

DECLARATION

I, Atsuko SANABE, translator of the attached document, do hereby certify that to the best of my knowledge and belief the attached document is the true English translation of Japanese Patent Application No. 2002-239622 (which corresponds to Japanese Patent Publication No. 2004-74643) duly filed with the Japan Patent Office on August 20, 2002.

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5	[Name of Document]	Specification
	[Title of Invention]	Color Shift Correcting Method, Optical Writing Device and Image Forming Apparatus
	[Scope of Claims]	
	[Claim 1]	
10	A color shift correcting method for correcting a color shift caused by misregistration of images in different colors when latent images written onto an image carrier by an optical writing means, and visualized in different colors, are transferred directly or indirectly onto a movable element to form a color image, the color shift correcting	
15	method being characterized in that the color shift among the respective color images is corrected by adjusting an irradiation position in a sub-scanning direction of a light beam emitted from the optical writing means while the optical writing means emits the light beam to form a latent image.	
20	[Claim 2]	
	The color shift correcting method according to claim 1, characterized in that a step of adjusting the irradiation position of the light beam in the sub-scanning direction is performed based on a result of reading a pattern for detecting a color shift among	
25	the visualized images which have been written onto the image carrier prior to start of the adjustment.	
	[Claim 3]	
	The color shift correcting method according to claim 2, characterized in that timing at which the pattern is written is set	
30	based on timing at which a reference point provided on the image carrier is detected.	
	[Claim 4]	
	The color shift correcting method according to claim 2,	

characterized in that timing at which the pattern is written is set based on timing at which a reference point provided on an intermediate transfer element is detected.

[Claim 5]

5 The color shift correcting method according to claim 1, characterized in that the adjustment in the sub-scanning direction includes a step of correcting timing at which the optical writing means writes an image, and a step of correcting a beam position of light beam, and the both steps are executed in parallel.

10 [Claim 6]

 The color shift correcting method according to claim 5, characterized in that the step of correcting the writing timing corrects a portion corresponding to a quotient obtained by dividing a misregistration amount by a dot pitch, and the step of correcting
15 the beam position corrects a portion corresponding to a residual resulting from the division of the misregistration amount by the dot pitch.

[Claim 7]

 An optical writing device including a plurality of optical writing
20 means which irradiates an image carrier with a light beam based on input image information for performing optical writing to form an image in a plurality of colors, characterized by comprising an adjustment means for adjusting a position on the image carrier at which a light beam from the optical writing device is irradiated, while performing
25 the optical writing on the image carrier to form latent images, such that the light beam irradiation positions match with one another when the images of respective colors are superimposed.

[Claim 8]

 The optical writing device according to claim 7, characterized in
30 that the optical writing means comprises a laser beam emitting device and a coupling optical system, and the adjustment means is comprised of a holding member for integrally holding the laser beam emitting device and the coupling optical system, and a driving mechanism for

moving the holding member in a sub-scanning direction.

[Claim 9]

5 The optical writing device according to claim 8, characterized in that the holding member is supported by an optical housing while holds an optical deflector and another optical device for irradiating a light beam onto an image carrier such that the holding member is capable of rotating around a support axis in an eccentric state to an optical axis of the light beam.

[Claim 10]

10 The optical writing device according to claim 9, characterized in that a driving mechanism rotatably drives the holding member around the support axis.

[Claim 11]

15 The optical writing device according to claim 9, characterized in that an eccentricity of the optical axis of the light beam to a rotation center of the holding member is set such that the optical axis of the light beam substantially matches the rotation center axis of the holding member at a light beam deflecting position.

[Claim 12]

20 The optical writing device according to claim 8, characterized in that the holding member is provided with a set of guide members in parallel with an image carrier in the sub-scanning direction in an optical housing for holding an optical deflector and another optical device for irradiating a light beam onto the image carrier, and the holding member is movably supported along the set of guide members.

[Claim 13]

The optical writing device according to claim 12, characterized in that a driving mechanism moves the holding member in parallel along the set of guide members.

30 [Claim 14]

The optical writing device according to claim 12, characterized in that a curvature of the set of guide members is set such that the optical axis of the light beam substantially matches at a light beam

deflecting position of the optical deflector when the optical axis of the light beam is moved.

[Claim 15]

An image forming apparatus in which at least one image forming means
5 having one image carrier forms images in different colors, and the
images in different colors formed by the image forming means are
directly or indirectly transferred onto a movable element to form an
image, the image forming apparatus being characterized by comprising
the optical writing device according to any one of claims 7 through
10 14.

[Claim 16]

The image forming apparatus according to claim 15 further
comprising a color shift detection means for detecting an amount of
color shift based on a plurality of patterns formed on the movable
15 element to detect the color shift of respective colors, characterized
in that an adjustment means adjusts the amount of color shift detected
by the color shift detection means to correct the color shift.

[Claim 17]

The image forming apparatus according to claim 15, characterized
20 by comprising:

a reference position mark provided to detect a rotation phase of
the image carrier;

a detection means for detecting the reference position mark; and

a computing means for detecting an amount of color shift on each
25 color image formed on the movable element based on a position where
the reference position mark is detected to calculate a color shift
correction value corresponding to each of the colors,

and also characterized in that an adjustment means corrects the
color shift by adjusting a light beam irradiation position on an image
30 carrier of associated colors based on the detected reference position
marks and a plurality of calculated color shift correction values
corresponding to each of the colors.

[Claim 18]

The image forming apparatus according to claim 15, characterized by comprising:

a reference position mark provided for detecting a rotation phase of the movable element;

5 a detection means for detecting the reference position mark; and

a computing means for detecting an amount of color shift on each color image formed on the movable element based on a position where the reference mark is detected to calculate a color shift correction value corresponding to each of the colors,

10 and also characterized in that an adjustment means corrects the color shift by adjusting a light beam irradiation position on an image carrier of associated colors based on the detected reference position marks and a plurality of calculated color shift correction values corresponding to each of the colors.

15 [Claim 19]

The image forming apparatus according to claim 17 or 18, characterized in that the adjustment means includes a writing timing control circuit for controlling timing at which a light beam is irradiated onto image carriers based on the reference position marks
20 provided on respective image carriers and the plurality of calculated color shift correction values, and a beam position control circuit for controlling the irradiation position of the light beam.

[Claim 20]

The color shift correcting method according to claim 19,
25 characterized in that:

the writing timing control circuit receives input of quotient obtained by dividing an amount of color shift by a dot pitch;

the writing timing control circuit modulates a laser beam emitting device based on the quotient;

30 the beam position control circuit receives a residual resulting from the deviation of the amount of color shift by the dot pitch; and

the beam position control circuit moves an optical housing based on the residual.

[Claim 21]

The image forming apparatus according to claim 17 or 18,
characterized by comprising:

a memory for storing the plurality of color shift correction values;

5 and

a reading means for reading out the plurality of color shift
correction values stored in the memory.

[Detailed Description of the Invention]

[0001]

10 [Technical Field of the Invention]

The present invention relates to a color shift correcting method,
an optical writing device, and an image forming apparatus for
correcting a color shift when an image is formed in a plurality of
colors. More specifically, the present invention relates to a color
15 shift correcting method, an optical writing device and an image forming
apparatus for preventing a color shift from occurring when a color
image is formed by sequentially transferring a plurality of images
in different colors onto a transfer belt or a sheet on a transfer belt,
or onto an intermediate transfer element by a multiple image forming
20 apparatus including a plurality of image forming means such as a tandem
type color copier and a color printer, or by at least one image forming
means.

[0002]

[Background Art]

25 In recent years, colorization has been rapidly introduced into
documents processed in offices and the like, and image forming
apparatuses, such as a copier, a printer, a facsimile and the like,
which process such documents, have been rapidly colorized. At present,
color document processing apparatuses such as the ones described above
30 tend to form images with higher quality at faster processing speed
in order to satisfy increasing demands for a higher grade and higher
speed for business processing in offices and the like. To respond
to such demands, a variety of so-called tandem type color image forming

apparatuses having, for example, an image forming unit for each of black (K), yellow (Y), magenta (M) and cyan (c), have been proposed and commercially available. The tandem type color image forming apparatus directly or indirectly transfers a plurality of images in different colors, formed by respective image forming units, onto a conveyed transfer material or an intermediate transfer element, to form a color image thereon.

[0003]

Incidentally, since the tandem type color image forming apparatus configured as described above employs a system in which a plurality of image forming units are used to form a single image, it is possible to form a color image at extremely high speed. However, if the image formation is speeded up, accurate alignment of images formed by the respective image forming units, i.e., accurate color registration (referred to as "registration" hereinafter) may not be achieved, so that it is extremely difficult to achieve a balance between higher image quality and faster processing speed. The achievement in a suitable balance between higher image quality and faster processing speed is subject to a position and a size of each image forming unit of the color image forming apparatus, and a subtle change in a position and a size of parts in the image forming units. In this connection, Japanese Laid-Open Publication No. 2000-3121 proposed an apparatus for reducing a color shift by forming a pattern for detecting a color shift on a transfer member or the like, detecting the pattern using a reading sensor, measuring an amount of the color shift, and then adjusting an image writing timing.

[0004]

The above described correction method detects and corrects a color registration shift in a certain size and orientation (referred to as "DC color shift" hereinafter), which is caused by a subtle change in the position and the size of the respective image forming units and in the position and size of parts in the image forming units due to a temperature change within the color image forming apparatus and an

external pressure applied to the color image forming apparatus.

[0005]

However, in the apparatuses, if a writing means for each color employs a polygon mirror based optical deflector, a correction is generally made per unit of scanning. Specifically, since a 600 dpi image is corrected per unit of approximately 42 μm , an associated correction error is included in a narrow sense. To eliminate such a correction error, it is necessary to adjust respective optical deflectors by controlling a rotation phase before the optical deflector starts to write an image in its associated color. As has been described, for adjusting the rotation phase of the optical deflector, the rotation of optical deflector needs to be adjusted by temporally accelerated or decelerated. However, because the optical deflector rotates at high speed, the phase adjustment takes a long time and entails technical difficulties, and therefore results in overly high cost in adjusting the rotation phase of the optical deflector. In addition, in an image forming apparatus for deflecting laser beams of respective colors by a single deflector with an intention of reducing cost, respective color images are written at the same phase without exception, so that if misregistration for respective colors is corrected at the writing timing only, the misregistration during a single scanning operation of the deflector may not be corrected in theory.

[0006]

On the other hand, the color registration shift also includes, other than the one caused by a DC component, a color registration shift in a size and orientation, which vary periodically, mainly caused by a rotator such as a photoconductor, a belt drive roll or the like (referred to as "AC color shift" hereinafter). Referring to the AC color shift, Japanese Laid-Open Publication No. 2000-199988 describes that the AC color shift occurs due to changes in over time (abrasion) in a thickness of a belt, a driving roller and the like in a case of using transfer belt member.

[0007]

Further, to accommodate the AC color shift, a conventional color image forming apparatus detects a fluctuation of the rotation speed of a photoconductor drum using an encoder attached to a rotating shaft
5 of the photoconductor drum or the like, and feeds the fluctuation of the rotation speed of the photoconductor drum or the like detected by the encoder forward or back to the driving motor to reduce the fluctuations in the rotation of the photoconductor drum.

[0008]

10 [Problems to be Solved]

However, even if the photoconductor drum or the like are controlled to reduce its fluctuations in the rotation based on the detection information from the encoder as described above, the photoconductor drum itself includes eccentricities, or a surface of the
15 photoconductor drum includes eccentricities caused by installation of the photoconductor drum. In addition, in a specific configuration, eccentricities may be caused by a clearance error of the rotating shaft of the photoconductor drum. It has been a problem in which the AC color shift caused by the above factors results in image degradation.

20 [0009]

To resolve the foregoing problem, Japanese Laid-Open Publication No. Hei 9-146329 proposes an invention in which at least one rotation phase of the rotating member, such as the photoconductor drum, the belt drive roll or the like, to be individually adjusted, so that
25 degradation of image quality caused by the AC color shift due to the above-described factors is suppressed. In the proposal, speed of the photoconductor drum, the transfer belt and the like is controlled to perform a method of eliminating the AC color shift. However, such a method requires a very precise control and parts of great precision,
30 as a result, inevitably increases the cost.

[0010]

In addition, even the aforementioned method is applied, when a fluctuation in rotating angle speeds of the respective photoconductor

drums fluctuates at the same amplitude, an amount of color shift caused by the fluctuation in rotating angle speeds of the photoconductor drum may not be eliminated. However, in reality, the rotating angle speed does not always fluctuate over the same amplitude, so that the color shift is not satisfactory eliminated in a strict sense. Further, since the respective photoconductor drums are driven by independent driving sources in order to match the rotation phase of the respective photoconductor drums, it also causes an increase in the cost.

[0011]

Furthermore, a case where the AC color shift is aggravated when the belt has an uneven thickness, is considered. For example, a diameter of a belt neutral plane (diameter of pitch circle) is calculated by: $D+T$ (mm), where a diameter of a driving roller of the belt is D (mm), the thickness of the belt is T (mm), and an image forming speed is V (mm/sec).

From the foregoing, a distance extending over respective image forming units is calculated by: $N \times \pi \times (D+T)$ where N is an integer. Therefore, for reducing the apparatus to the smallest size possible, the distance extending over the respective image forming units is calculated by: $\pi \times (D+T)$ (mm).

Assuming that ΔT is a difference in the thickness of the belt, the amount of fluctuations in the image forming speed is calculated by:
 $(\Delta T) / (T+D) \times V$ (mm/sec) ... (1)

[0012]

Generally, since a full color image is formed by four image forming units, a distance between the image forming units at both extreme ends is calculated by: $3 \times \pi \times (T+D)$ (mm), and at a normal image forming speed, a time required for a sheet to pass through the four image forming units is calculated by: $3 \times \pi \times (T+D) / V$ (sec) ... (2)

Therefore, an amount of misregistration on an image, which occurs if the roller is worn away, between the image forming units at both extreme ends, is found by multiplying the equation (1) by the equation (2): $3 \times \pi \times (\Delta T)$... (3)

[0013]

Specifically, even if there is merely 10 μm of difference in the belt thickness, the amount of color shift mounts up to approximately 94 μm , as calculated from the equation (3). In other words, when the resolution is 600 dpi, a shift exceeding two pixels is repeated every cycle of the belt, and as a result, the AC color shift occurs.

[0014]

While such an AC color shift may be eliminated by controlling the speed of the transfer belt or the like as mentioned above, it requires a very precise control and parts of great precision, and therefore inevitably increases the cost.

[0015]

The present invention has been made in view of the actual circumstances of the prior art, and it is an object of the present invention to provide a color shift correcting method and an optical writing device, which are capable of accurately correcting a color shift in a sub-scanning direction.

[0016]

It is another object of the present invention to provide a color shift correcting method and an optical writing device, which are capable of accurately correcting a color shift due to dynamic factors, such as fluctuations in speed of an image carrier and intermediate transfer element, at a low cost without employing a driving motor rotation control means or an encoder.

[0017]

It is another object of the present invention to provide an image forming apparatus capable of forming an image at high grade by accurately correcting a color shift.

[0018]

[Means for Solving the Problems]

In order to achieve the above objective, a first means is characterized in that with a color shift correcting method for correcting a color shift caused by misregistration on the images in

different colors when a color image is visualized by developing latent images written onto an image carrier by an optical writing means, and directly or indirectly transferring the visualized image in different colors onto a movable element, a color shift among the respective color
5 images is corrected by adjusting an irradiation position of an light beam emitted from the optical writing means in a sub-scanning direction while the optical writing means emits the light beam to form a latent image. According to the first means, since the irradiation position of the light beam emitted from the optical writing means in the
10 sub-scanning direction is adjusted while the latent image is formed to correct the color shift among the respective colors, it is possible to eliminate a color shift which presents periodical fluctuations in sizes or orientations.

[0019]

15 A second means is characterized in that in the first means, a step of adjusting the irradiation position of the light beam in the sub-scanning direction is performed based on a result of reading a pattern for detecting the color shift among visualized images which have been written onto the image carrier prior to start of the
20 adjustment. According to the second means, the irradiation position of the laser beam in the sub-scanning direction is adjusted based on the developed patter, which has been actually written onto the image carrier, it is possible to perform the accurate adjustment.

[0020]

25 A third means is characterized in that in the second means, timing at which the pattern is written is set based on timing at which a reference point provided on the image carrier is detected. According to the third means, it is possible to eliminate the color shift which presents periodical fluctuations in sizes or orientations due to
30 fluctuations in rotating speed of the image carrier.

[0021]

A fourth means is characterized in that in the second means, timing at which the pattern is written is set based on timing at which a

reference point provided on an intermediate transfer element is detected. According to the fourth means, it is possible to eliminate the color shift which presents periodical fluctuations in sizes or orientations due to fluctuations in speed of the intermediate transfer
5 element.

[0022]

A fifth means is characterized in that in the first means, the adjustment in the sub-scanning direction includes a step of correcting timing at which the optical writing means writes an image, and a step
10 of correcting the beam position of light beam, and the both steps are executed in parallel. According to the fifth means, since the steps of correcting the timing at which the optical writing means writes an image, and correcting the beam position of light beam are executed in parallel, it is possible to correct the color shift rapidly.

15 [0023]

A sixth means is characterized in that in the fifth means, the step of correcting the writing timing corrects a portion corresponding to a quotient obtained by dividing a misregistration amount by a dot pitch, and the step of correcting the beam position corrects a portion
20 corresponding to a residual resulting from the division of the misregistration amount by the dot pitch. According to the sixth means, since both a large and small misregistration are independently corrected such that the large misregistration is corrected in the step of correcting the writing timing, and the small misregistration is
25 corrected in the step of correcting the beam position, it is possible to correct the color shift accurately.

[0024]

A seventh means is characterized in that an optical writing device having a plurality of optical writing means, which irradiate an image
30 carrier with a light beam based on input image information, for performing optical writing to form an image in a plurality of colors, includes an adjustment means for adjusting a position on the image carrier at which a light beam from the optical writing device is

irradiated, while performing the optical writing on the image carrier to form latent images, such that the light beam irradiation positions match with one another when the images of respective colors are superimposed. According to the seventh means, since the irradiation position of the light beam emitted from the optical writing means in the sub-scanning direction is adjusted while a latent image is formed, and adjusted such that the irradiation positions of light beams on the image carrier is adjusted in the sub-scanning direction match with one another when the images of respect colors are superimposed, it is possible to eliminate the color shift which presents periodical fluctuations in sizes or orientations.

[0025]

An eighth means is characterized in that in the seventh means, the optical writing means includes a laser beam emitting device and a coupling optical system, and the adjustment means includes a holding member for integrally holding the laser beam emitting device and the coupling optical system, and a driving mechanism for moving the holding member in a sub-scanning direction. According to the eighth means, since the writing position of the light beam in the sub-scanning direction may be displaced by moving the holding member, which integrally includes the laser beam emitting device and the coupling optical system, in the sub-scanning direction while maintaining a relative position between the laser beam emitting device and the coupling optical system, it is possible to correct the color shift with a simple configuration.

[0026]

A ninth means is characterized in that in the eighth means, the holding member is supported by an optical housing while holds an optical deflector and another optical device for irradiating a light beam onto an image carrier such that the holding member is capable of rotating around a support axis in an eccentric state to an optical axis of the light beam. According to the ninth means, since the irradiation position of the light beam may be displaced with a simple

configuration by causing the holding member to rotate on the support axis, thereby correcting the color shift with high accuracy.

[0027]

5 A tenth means is characterized in that in the ninth means, the driving mechanism is rotatably driven the holding member around the support axis. According to the tenth means, it is possible to accurately displace the irradiation position of the light beam by causing the holding member to drive the holding member to rotate, thereby correcting the color shift with high accuracy.

10 [0028]

A eleventh means is characterized in that in the ninth means, an eccentricity of the optical axis of the light beam to a rotation center of the holding member is set such that the optical axis of the light beam substantially matches the rotation center axis of the holding member at a light beam deflecting position. According to the eleventh means, since the rotation center axis of the holding member and the optical axis of the light beam substantially match at the light beam deflecting position of the light deflector, even if the holding member is rotated, optical characteristic does not change. Further, since
15 the light beam irradiation position on the image carrier does not largely move to a main scanning direction, a color shift does not occur in the main scanning direction, and it is possible to perform the optical writing for obtaining images having higher quality.

[0029]

25 A twelfth means is characterized in that in the eighth means, the holding member is provided with a set of guide members in parallel with the image carrier in the sub-scanning direction in the optical housing for holding the optical deflector and another optical device for irradiating a light beam onto the image carrier, and the holding
30 member is rotatably supported along the set of guide members. According to the twelfth means, it is possible to displace the light beam irradiation position on the image carrier with a simple configuration by moving the holding member along the set of guide

members, thereby correcting the color shift with high accuracy.

[0030]

5 A thirteenth means is characterized in that in the twelfth means, the driving mechanism moves the holding member in parallel along the set of guide members. According to the thirteenth means, it is possible to displace the beam irradiation position accurately by simply translating the holding member by the driving mechanism, thereby correcting the color shift with high accuracy.

[0031]

10 A fourteenth means is characterized in that in the twelfth means, a curvature of the set of guide members is set such that the optical axis of the light beam substantially matches at the light beam deflecting position of the optical deflector when the optical axis of the light beam is moved. According to the fourteenth means, since
15 the curvature of the set of guide members is set such that the optical axis of the light beam substantially matches at the light beam deflecting position of the optical deflector when the optical axis is moved, even if the holding member is moved, optical characteristic does not change. Further, since the light beam irradiation position
20 on the image carrier does not move in the main scanning direction, the color shift in the main scanning direction does not occur, and it is possible to perform the optical writing for obtaining images having higher quality.

[0032]

25 A fifteenth means is characterized in that the image forming apparatus, in which at least one image forming means having one image carrier forms images in different colors, and the images in different colors formed by the image forming means are directly or indirectly transferred onto the movable element to form an image, includes the
30 optical writing device according to any one of claims 7 through 14. According to the fifteenth means, it is possible to perform the optical writing such that the color shift, which presents periodical fluctuations in sizes and orientation, does not occur, thereby

obtaining images having higher quality.

[0033]

A sixteenth means is characterized in that in the fifteenth means, the image forming apparatus according to claim 15 further includes
5 a color shift detection means for detecting an amount of color shift based on a plurality of patterns formed on the movable element to detect the color shift of respective colors, and the adjustment means adjusts the amount of color shift detected by the color shift detection means to correct the color shift. According to the sixteenth means, since
10 the light beam irradiation position in the sub-scanning direction is adjusted based on the developed pattern, it is possible to perform the position adjustment at high accuracy, and to obtain images having higher quality.

[0034]

15 A seventeenth means is characterized in that in the fifteenth means, the image forming apparatus includes a reference position mark provided to detect a rotation phase of the image carrier, a detection means for detecting the reference position mark, and a computing means for detecting an amount of color shift on each color image formed on
20 the movable element based on a position where the reference position mark is detected to calculate a color shift correction value corresponding to each of the colors, and the adjustment means corrects the color shift by adjusting a light beam irradiation position on the image carrier of associated colors based on the detected reference
25 position marks and a plurality of calculated color shift correction values corresponding to each of the colors. According to the seventeenth means, since the color shift due to fluctuations in the rotating speed of the image carrier is corrected by adjusting the irradiation position the light beam irradiated from the optical
30 writing means during the formation of a latent image toward the sub-scanning direction, it is possible to eliminate the color shift, which presents periodical fluctuations in sizes and orientations, due to fluctuations in the rotating speed of the image carrier, and to

obtain images having higher quality.

[0035]

A eighteenth means is characterized in that in the fifteenth means, the image forming apparatus includes a reference position mark
5 provided for detecting a rotation phase of the movable element, a detection means for detecting the reference position mark, and a computing means for detecting an amount of color shift on each color image formed on the movable element based on a position where the reference mark is detected to calculate a color shift correction value
10 corresponding to each of the colors, and the adjustment means corrects the color shift by adjusting the light beam irradiation position on the image carrier of associated colors based on the detected reference position marks and calculated color shift correction values corresponding to each of the colors. According to the eighteenth
15 means, the amount of color shift is accurately calculated from the pattern image, the reference position mark on the image carrier is detected during the image formation, an image is formed at the same phase at which the color shift is measured, and then the beam irradiation positions on each of the image carriers are adjusted based
20 on the calculated color shift correction values of respective colors during the formation of a latent image, thereby correcting the color shift accurately and rapidly.

[0036]

A nineteenth means is characterized in that in the seventeenth or
25 eighteenth means, the adjustment means includes a writing timing control circuit for controlling timing at which a light beam is irradiated onto the image carriers based on the reference position marks provided on respective image carriers and the plurality of calculated color shift correction values, and a beam position control
30 circuit for controlling an irradiation position of the light beam. According to the nineteenth means, since an operation of the writing timing control circuit for controlling timing at which a light beam is irradiated onto the image carriers based on the calculated color

shift correction values, and an operation of the beam position control circuit for controlling the irradiation position of the light beam may be independently executed in parallel, it is possible to perform the rapid correction control.

5 [0037]

A twentieth means is characterized in that in the nineteenth means, the writing timing control circuit receives input of quotient obtained by dividing an amount of color shift by a dot pitch, and modulates a laser beam emitting device based on the quotient, and the beam
10 position control circuit receives a residual resulting from the deviation of the amount of color shift by the dot pitch, and moves an optical housing based on the residual. According to the twentieth means, since an amount of large misregistration corresponding to the quotient is corrected through the writing timing control, and an amount
15 of small misregistration corresponding the residual is corrected through the beam position control, the large and small misregistration are corrected through different collection methods. Therefore it is possible to correct accurately and rapidly.

[0038]

20 A twenty-first means is characterized in that in the seventeenth or eighteenth means, the image forming apparatus includes a memory for storing the plurality of color correction values, and a reading means for reading out the plurality of color correction values stored in the memory. According to the twenty-first means, since the color
25 correction value is read out from the memory to correct the color shift, it is possible to repeatedly perform the color shift correction.

[0039]

[Description of the Preferred Embodiments]

In the following, embodiments of the present invention are
30 described with reference to drawings.

In the following embodiments, like parts are designated the same reference numerals, and a repeated description is omitted when appropriate.

[0040]

1. First Embodiment

1.1 General Configuration of an Apparatus

Fig. 1 is a diagram illustrating a general configuration of a color
5 laser printer which embodies an image forming apparatus according to
a first embodiment. Fig. 2 is a plain view illustrating an optical
writing (exposure) device, and Figs. 3 and 4 are cross-sectional view
generally illustrating the optical writing (exposure) device.

[0041]

10 In Fig. 1, a color laser printer 1, which serves as the image forming
apparatus, employs a photoelectric image forming process and basically
includes an image generator block 2, a sheet feeder block 3 including
a sheet feeder cassette, and a fixer block 4. The image generator
block 2 includes a plurality of photoconductor drums 10, a plurality
15 of exposure units 6, a plurality of transfer units 5 and the like.
The plurality of photoconductor drums 10 (10Y, 10C, 10M, 10K) are
provided with, toward a rotating direction, charging units 8 (8Y, 8C,
8M, 8K), exposure units 6 (6Y, 6C, 6M, 6K), developing units 9 (9Y,
9C, 9M, 9K), transfer units 5 (5Y, 5C, 5M, 5K), and cleaning units
20 7 (7Y, 7C, 7M, 7K), respectively. In the following description, the
aforementioned components are collectively designated only by the
numerals, and Y, C, M, K are added to the numerals only when the
components needs to be described with respect to the respective colors.

[0042]

25 The charging unit 8 is formed of a roll-shaped conductive roller
which is applied with a charging bias voltage from a power supply unit
to uniformly charge a photosensitive layer formed on the surface of
the photoconductor drum 10. The exposure unit 6 irradiates the
surface of the photoconductor drum 10 with laser light (hereinafter
30 called the "laser beam L" (LY, LC, LM, LK)), which turns on and off
based on image data, to form an electrostatic latent image on the
photoconductor drum 10. The developing unit 9 is formed of a
developing roller, a developer container and the like for developing

the electrostatic latent image on the photoconductor drum 10. Color image forming apparatuses often have four developing means for yellow Y, cyan C, magenta M, and black K, as in the case with the color laser printer herein described for developing a color image. In the first
5 embodiment, as illustrated in Fig. 1, the four image generator blocks associated with a yellow (Y) image, a cyan (C) image, a magenta (M) image and a black (K) image are arranged in order from the left of the drawing (from an upstream side of an intermediate transfer belt, later described, in its rotating direction). However, since a full
10 color image may be formed even with three colors except for black K, i.e., yellow Y, cyan C and magenta M, an image forming apparatus may be designed without components associated with black K.

[0043]

The transfer unit 5 transfers an image developed on the
15 photoconductor drum 10 by toner from the photoconductor drum 10 to an intermediate transfer belt 11 through a transfer roller 12. As illustrated in Fig. 9, later described, the intermediate transfer belt 11 is extended between a driving roller 34 and a driven roller 36 and pressurizing roller 35. As the driving roller 34 rotates in a
20 direction indicated by an arrow A in Fig. 9, the intermediate transfer belt 11 moves in a direction indicated by an arrow B in Fig. 9. A toner image formed on each photoconductor drum 10 comes in contact with the intermediate transfer belt 11, and transferred onto the intermediate transfer belt 11 by applying a predetermined bias voltage
25 to the associated transfer roller 12 (12Y, 12C, 12M, 12K) disposed on the back of the intermediate transfer belt 11. The foregoing transfer is generally called the "primary transfer", and the transfer unit 5 is likewise called the "primary transfer unit". The cleaning unit 7 removes a developer remaining on the photoconductor drum 10
30 after the transfer before a next image creating operation is started.

[0044]

The transfer methods implemented in such a color image forming apparatus may be roughly classified into the following two. One is

referred to as an intermediate transfer method, in which images formed respectively by the plurality of photoconductor drums 10Y, 10C, 10M and 10K are superimposed onto the intermediate transfer belt 11, and then the superimposed image is transferred on a transfer material (it
5 is called the "secondary transfer"). The other one is referred to as a direct transfer method in which images formed on the photoconductor drums 10Y, 10C, 10M and 10K are directly transferred onto a transfer material such that the images are superimposed on the transfer material. The color laser printer 1 illustrated in Fig. 1
10 employs the former method.

[0045]

In the intermediate transfer method shown in the first embodiment, images superimposed on the intermediate transfer belt 11 are collectively transferred to a transfer material by a transfer roller
15 13 (called the "secondary transfer means"), which serves as a transfer means. The transfer material is often a recording material such a sheet of paper or the like (hereinafter also called the "transfer sheet"), and is stored in a sheet feeder cassette 3a of the sheet feeder block 3. Transfer sheets are separated and conveyed one by one by
20 a pickup roller 3b. Each of the transfer sheets individually separated and fed out by the pickup roller 3b is conveyed to the transfer roller 13, which serves as the secondary transfer means, by a pickup roller 3c, and then the full color toner images superimposed on the intermediate transfer belt 11 are transferred to the transfer
25 sheet. Subsequently, for fixing the resulting image, the transfer sheet is convey to the fixer block 4, which applies the transfer sheet with heat and pressure to fix the image on the transfer sheet. The resulting transfer sheet with the image fixed thereon is discharged to the outside of the apparatus from a sheet discharge roller 3e through
30 a conveyer roller 3d.

[0046]

It is to be noted that the recording sheet serves as a movable element in the direct transfer, while the intermediate transfer element

(intermediate transfer belt 11) serves as the movable element in the indirect transfer.

[0047]

1.2 Exposure Unit (Optical Writing Device)

5 Fig. 2 illustrates an internal configuration of the exposure unit 6 in detail. As may be seen in Fig. 2, the configuration of the exposure unit 6 is basically formed of a laser light source (unit) 61 for oscillating a laser beam L, a polygon mirror 62 which acts as a deflecting or scanning means for deflecting or scanning the laser beam
10 L modulated based on an image signal, a focusing optical system 63 for focusing the scanned laser beam L on the photoconductor drum 10 in a desired size, and a synchronization sensing unit 64 which acts as a synchronization sensing means for sensing a scan start timing for the laser beam L. The polygon mirror 62 is driven by a polygon
15 motor 62a at high speeds. In the first embodiment, for irradiating the four photoconductor drums 10 associated with Y, C, M, K images with the laser beams L, four laser light sources 61Y, 61M, 61C, 61K are provided and divided into two groups, i.e., light sources 61Y, 61C and light sources 61M, 61K, such that laser beams are incident
20 from both sides of the polygon mirror 62, as generally referred to as an "opposite scanning method".

[0048]

In the first embodiment, a semiconductor laser (LD) 61a is used for a light emission source, and the laser light source unit (LD unit)
25 61 is formed of the semiconductor laser 61a, a collimator lens 61b for substantially collimating divergent light emitted from the semiconductor laser 61a, a semiconductor laser driving circuit board 61c, and a holding member (base) 61d for holding the foregoing components. The laser beam L emitted from the LD unit 61 passes through
30 an aperture 65 and a cylinder lens 66, and reaches to the polygon mirror 62, as may be seen from Fig. 6 which generally shows a light path from the LD unit 61 to the polygon mirror 62. For independently irradiating two sets of laser beams LY, LC and LM, LK onto the polygon mirror 62

from the respective sides, mirrors 67a, 67b are provided on one light path, as shown in Fig. 2.

[0049]

When the polygon mirror 62 is rotated at high rotational speed
5 beyond 30,000 rpm, a sound-proof glass is often provided in front of the polygon mirror 62 for countermeasures to noise and the like. Fig. 2 shows a configuration in which sound-glasses 68 are provided on both sides of the polygon mirror 62.

[0050]

10 The laser beam deflected or scanned by the polygon mirror 62 is incident on the focusing lens 63 again through the sound-proof glass 68. Subsequently, the laser beam L, which is guided to the photoconductor drum 10, passes through the mirror 69 and reaches the photoconductor drum 10. The angle at which the surface of the
15 photoconductor drum 10 is irradiated with the laser beam L is set substantially the same for each of Y, C, M, K colors. On the other hand, for synchronization sensing for determining a timing at which a write is started, the laser beam L passing through the focusing lens 63 is returned back by a synchronization sensing mirror 64a so that
20 the laser beam L reaches the synchronization sensing unit 64. The synchronization sensing unit 64 includes a focusing lens 64b, an electric circuit board 64c having a photoelectric element, and a holding member 64d for holding the foregoing components.

[0051]

25 Since the synchronization sensing essentially means that a timing is taken for the scanning light, the sensing unit is generally disposed prior to the scanning, however, in the first embodiment, a sensing means is also disposed after the scanning for sensing fluctuations in the speed of scanning (or time). Fig. 2 illustrates the
30 configuration for taking the synchronization before and after the scanning. In the example, the single synchronization sensing unit 64 senses upper and lower scanning light.

[0052]

Figs. 3 and 4 show example configurations in which laser light is emitted from a single optical deflector to all of the plurality of photoconductor drums 10Y, 10C, 10M, 10K. The difference between the two example configurations lies in that one or two polygon mirrors
5 62 are provided. Both have their respective advantages and disadvantages, so that either of them may be employed. In addition, though not shown, separate exposing means may be provided one by one for the plurality of photoconductor drums. For example, four exposing means may be provided for four photoconductor drums, respectively,
10 to write the laser beams onto the associated photoconductor drums. In Figs. 3 and 4, dustproof glasses 60Y, 60C, 60M, 60K are provided at respective exits from the exposing units 6 to the photoconductor drum 10 for preventing dust from introducing into the exposing means.

[0053]

15 1.3 Beam Irradiation position Adjusting Mechanism

For a method for displacing a laser beam irradiation position toward the sub-scanning direction, there is a method for displacing the laser irradiation position on the photoconductor surface 10a of the photoconductor drum 10 by displaying the LD unit 61, which is formed
20 of the holding member 61d for holding the semiconductor laser 61a and collimator lens (coupling optical system) 61b, toward the sub-scanning direction, as illustrated in Figs. 5A and 5B. Fig. 5A shows an example in which the LD unit 61 is displaced in parallel (moved upward in the figure), while Fig. 5B shows an example in which the LD unit 61 is
25 displaced in parallel, and the angle is also adjusted such that the irradiation position matches on the mirror surface 62b of the polygon mirror 62.

[0054]

In an alternative, the return mirror 69 in the optical writing
30 device is displaced to change the position at which the laser beam is irradiated. However, such a method is not practical in practice because a small change in angle causes a large displacement of the irradiation position, thus giving rise to a problem in terms of

accuracy. In another alternative, a glass-like plate material may be the inserted obliquely into the laser beam L in front of the polygon mirror 62 on which the laser beam L is incident. The angle of the glass-like plate material to the laser beam L may be changed to move
5 the beam position in the sub-scanning direction. The technique, however, involves an increase in the number of parts, and may adversely affect the beam focusing performance depending on the accuracy of the surface of the glass-like plate material. Any technique is employed as long as it may precisely control the position of the laser beam
10 L. Examples of the techniques are described later.

[0055]

From the foregoing, the first embodiment employs a position adjustor for the holding member 61, which is configured as illustrate in Fig. 7. Fig. 7 is a front view of the position adjuster according
15 to the first embodiment, wherein the LD unit 61 in Fig. 7 is viewed on the side from which the laser beam L exists. Specifically, the LD unit 61 is formed of the semiconductor laser (LD) 61a serving as the laser light source, a collimator lens 61b for substantially collimating divergent light emitted from the semiconductor laser 61a,
20 a semiconductor laser driving circuit board 61c, and a holding member (base) 61d for holding the aforementioned components. An arm 61 e extends in a direction corresponding to the main scanning direction of the holding member 61d, and below the arm 61e in the drawing, there is a beam position moving motor 70 which includes a stepping motor,
25 and a lead screw 71 driving by the beam position moving motor 70. The amount of advancement and retraction of the lead screw 71 is controlled by the rotating angle (the number of steps) of the beam position moving motor 70. The lead screw 70 is provided for concentrically and integrally rotating with the rotating shaft of the beam position moving
30 motor 70, and is engaged with a thread 61i formed on the arm 61e to convert the rotation of the lead screw 71 into the advancement and retraction (here, rotation) of the arm 61e.

[0056]

As illustrated in Fig. 7, the holding member 61 is supported for being rotatable about the axis of rotation 61f near the collimator lens 61. The optical axis 61g of the laser beam L emitted from the collimator lens 61 is moved in accordance with the position of the arm 61e. Therefore, the position of the laser beam L defined by the optical axis 61g may be precisely moved on the photoconductor surface 10a in microns in accordance with the rotation of the beam position moving motor 70. Fig. 8 is an explanatory diagram showing the position of the laser beam L on the photoconductor surface 10a, wherein the rotation of the holding member 61d about the axis of rotation 61f causes the laser beam L to rotate about the center of rotation 10b on the photoconductor surface 10a, so that the laser beam L moves in the sub-scanning direction.

[0057]

In Fig. 8, a hatched circle indicates the position (beam spot position) of the laser beam L emitted from the LD 61a on the photoconductor surface 10a which is located furthest away from the center of rotation 61f in the main scanning direction when the optical axis 61g of the laser beam L is displaced. Also, the laser beam L is irradiated at positions indicated by broken-line circles above and below the hatched circle after the optical axis 61 is displaced in the sub-scanning directions about the center of rotation 61f. The position of the LD 61b matches the hatched circle shown in Fig. 8, formed by the laser beam L emitted therefrom, when a correction value of the beam irradiation position is zero.

[0058]

Specifically, in the first embodiment, for precisely moving the position of the laser beam L in the sub-scanning direction in microns, the LD unit 61, which is formed of the holding member 61 for holding the laser light emitting element (LD 61a) and a coupling optical system (collimator lens 63), is rotatably mounted in an optical housing which also accommodates other optical elements for irradiating the polygon mirror 62 and photoconductor drum 10 with the laser beam L. Also,

there is a predetermined gap G between the axis of rotation 61f of the LD unit 61 and the optical axis 61g of the laser beam L mainly in the main scanning direction. Then, the axis of rotation 61f of the LD unit 61 is substantially matched with the optical axis 61g of the laser beam L at the position at which the laser beam L is deflected on the mirror surface 62b of the polygon mirror 62, and the LD unit 61 is rotated relative to an aperture 65 for shaping the laser beam L secured in the optical housing. With such a configuration, even if the LD unit 61 is rotated, light flux passing the aperture 65 onward does not largely change, so that the position of the laser beam L may be controlled on the photoconductor surface 10a at a resolution of several μm .

[0059]

Generally, the aperture 65 is often mounted in the LD unit 61 for shaping the light beam. If the LD unit 61 is moved in a condition that the LD unit 61 is mounted with the aperture 65, the position of the laser beam L on the photoconductor surface 10a largely moves in the sub-scanning direction, so that it is not appropriate for controlling the position at a resolution of several μm . In other words, although the aperture 65 may be mounted in the LD unit 61 for an apparatus in which the position of the laser beam L is largely moved for adjustment, the aperture 65 needs to be provided separately from the LD unit 61 for an apparatus in which the position of the laser beam L needs to be controlled at a resolution of several μm , as is the case with the embodiment.

[0060]

1.4 Mechanism for Driving Photoconductor Drum and Intermediate Transfer Belt

Fig. 9 generally illustrates a driving mechanism for rotating the photoconductor drums 10Y, 10C, 10M, 10K and the intermediate transfer belt 11 in the image generator block 2 in Fig. 1. As described above, the intermediate transfer belt 11 is extended between the driving roller 34, driven roller 36, and pressure roller 35, and is driven

by the belt driving motor 30. The belt driving motor 30 drives the belt driving roller 34 through a timing belt 33 extended between an integrally rotated motor pulley 31 concentrically attached to the driving shaft of the belt driving motor 30 and an integrally rotated driving pulley 33 disposed concentrically with the driving roller 34 to consequently rotate the intermediate transfer belt 11.

[0061]

The photoconductor drum 10Y, 10C, 10M, 10K provided for the respective colors are in contact with the transfer surface (front surface) of the intermediate transfer belt 11, and are rotated by concentric coupling photoconductor drums 10Y, 10C, 10M, 10K which are coupled to and driven by rotation coupling gears (idler gears) 22a, 22b disposed at two locations. A driving motor gear 20, which is concentrically attached to the rotating shaft of the drum driving motor 19 for integral rotation, comes into mesh with photoconductor drum gears 21C, 21M associated with the cyan photoconductor drum 10C and magenta photoconductor drum 10M. The driving force is transmitted, on one hand, to the photoconductor drum gear 21Y of the yellow photoconductor drum 10Y through the photoconductor drum gear 21C associated with the cyan photoconductor drum 10C and the rotation coupling gear 22a, and transmitted, on the other hand, to the photoconductor drum gear 21K associated with the black photoconductor drum 10K through the photoconductor drum gear 21M associated with the magenta photoconductor drum 10M and the rotation coupling gear 22b. Consequently, the single motor 19 may synchronously drive the four photoconductor drums 10Y, 10C, 10M, 10K in the same direction. The gears 21Y, 21C, 21M, 21K have the diameter and the number of teeth equal to those of the rotation coupling gears 22a, 22b, thereby driving the four photoconductor drum 10Y, 10C, 10M, 10K at the same peripheral speed.

[0062]

In the first embodiment, a color shift sensor 38 is provided at a location downstream of the belt driving roller 34 in the direction

in which the intermediate transfer belt is rotated, so that a color shift (misregistration) may be detected at the position. The color shift sensor 38 detects a color shift detection pattern (an image) PN formed on the intermediate transfer belt 11 to detect a color shift.

5 More specifically, for acquiring data, which is a base for the color shift correction, a color shift detection pattern (image) PN as illustrated in Fig. 10A is marked on the intermediate transfer belt 11, and is detected by the color shift detection sensor 38 at a resolution of approximately 5 μm to acquire color shift data. The

10 color shift detection pattern PN includes an image of lines having a fixed length along the main scanning direction and spaced from each other by predetermined gaps in the sub-scanning direction, and is formed by the photoconductor drums 10Y, 10C, 10M, 10K associated with the respective colors. The predetermined gaps are respectively given

15 by times t_1 , t_2 , t_3 (see Fig. 10B), which are calculated when the photoconductor drum 10 and intermediate transfer belt 11 are driving at a set speed. Actually, the gaps vary due to fluctuations in speed, so that the amount of change is detected from comparison with a reference value to detect a color shift (misregistration). It is to

20 be noted that since the color shift occurs due to a shift of a write position, the terms "color shift" and "misregistration" are used in the same sense of the first embodiment unless otherwise noted.

[0063]

The rotational speed of the photoconductor drum 10 may be fluctuated

25 due to uneven rotation of the driving motor 19, accumulated pitch errors and eccentricity of the driving motor gear 20, accumulated pitch errors and eccentricities of the rotation coupling gears 22a, 22b, and the like. While the first embodiment is described in connection with the gears because the driving mechanism is implemented by a gear

30 train, the same applies to a driving mechanism which is implemented by pulleys. In this way, the rotational speed of the photoconductor drum 10 may fluctuate due to the respective driving elements, resulting in an AC color shift which fluctuates on a periodic basis.

[0064]

As described above, the driving force of the intermediate transfer belt in the indirect transfer mode or the transfer conveyor belt in the direct transfer mode is transmitted through the timing belt which
5 is extended between the motor pulley 31 and the roller driving pulley 33, in which case the AC color shift may be also occur due to uneven rotation of the belt driving motor 30, eccentricity of the driving motor pulley 31, eccentricity of the roller driving pulley 33, eccentricity of the belt driving roller 33, uneven belt thickness,
10 and the like.

[0065]

Fig. 11 is a graph which shows the result of a measurement of an AC color shift made by the color shift sensor 38 with the color shift detection pattern PN formed on the intermediate transfer belt 11. The
15 graph shows the amount of shift of a cyan image C with reference to a black image K. As may be seen, actually, a color shift may occur due to fluctuations in the rotational speeds of the intermediate transfer belt 11 and photoconductor drums 10, and a DC color shift may overlap with the AC color shift. Here, a color shift of 20 μm
20 in one direction corresponds to a DC color shift, and the AC color shift overlaps with such an amount of DC color shift.

[0066]

1.5 Misregistration Correction Control

Fig. 12 is a block diagram illustrating a configuration for
25 controlling a misregistration correction. A control circuit includes a registration controller 100 and a system controller 200. The registration controller 100 includes a color shift amount calculation circuit 110, a color shift correction value processing circuit 120, a sensor control circuit 130, and a Y-counter 140Y, an M-counter 140M,
30 a C-counter 140C associated with the colors Y, M, C, respectively. The outputs of the sensor control circuit 130, Y-counter 140Y, M-counter 140M, and C-counter 140C are applied to the color shift amount calculation circuit 110. The sensor control circuit 130

controls the color shift sensor 38 which applies respective color detection outputs to the Y-counter 140Y, M- counter 140M, and C-counter 140C. The color shift correction value processing circuit 120 is also provided with a memory 121 for storing color shift correction values.

5 [0067]

The system controller 200 includes a beam position control circuit 210, a motor driver 220, a write timing control circuit 230, and an LD modulation circuit 240. The beam position control circuit 210 drives beam position moving motors 70Y, 70M, 70C for moving respective
10 beam positions of Y-, M-, C-LD units 61 through the motor driver 220. The write timing control circuit 230 modulates LDs 61aY, 61aM, 61aC, 61aK for writing the respective colors through the LD modulation circuit 240.

[0068]

15 1.5.1 Calculation of Color Shift Correction Values

For correcting a color shift as shown in Fig. 12, color shift correction values (misregistration correction values) are calculated and are relied on for the correction. For this purpose, the color shift detection pattern PN in Fig. 10 is written on each photoconductor
20 drum 10, developed, and transferred onto the intermediate transfer belt 11. Then, the color shift sensor 38 measures the amount of color shift with reference to a preset color. In the first embodiment, K_{1i}, K_{2i}, K_{3i} are calculated with reference to the black K. In the following, a routine for calculating a misregistration (color shift) correction
25 value is described with reference to a flow chart of Fig. 13.

[0069]

In a routine shown the flowchart of Fig. 13, the first processing involves writing the color shift detection pattern PN on the respective photoconductor drums 10Y, 10C, 10M, 10K (steps, S101, S102),
30 developing the color shift detection pattern PN on each photoconductor drum and transferring the developed color shift detection pattern PN onto the intermediate transfer belt 11 (step S103). Then, the color shift sensor 38 reads the color shift detection pattern PN (step S104).

In this event, as illustrated in Fig. 12, an interval between outputs of the color shift sensor 38 is counted by respective counters 140Y, 140M, 140C associated with the respective colors, and the color shift calculation circuit 110 calculates the times t_1 , t_2 , t_3 , shown in Fig. 10, and calculates the amounts of color shifts K_{1i} , K_{2i} , K_{3i} from the
5 aforementioned times (step S105). Further, the correction value processing circuit 110 processes color shift correction values (the number of steps by which the beam position moving motor 70 is rotated for the associated LD unit 61) D_{1i} , D_{2i} , D_{3i} (step S106). The
10 correction values except for the correction value for the reference color are stored in the memory 121 (step S107). The correction values D_1 , D_2 , D_3 are compared with a threshold value A (step S108). If larger than the threshold value A (No at step S108), the beam position is again adjusted based on the correction values D_1 , D_2 , D_3 , while a color
15 shift pattern is again formed (steps S109, S110, S102). Then, the color shift correction values D_{1i} , D_{2i} , D_{3i} are calculated again (steps S103, S104, S105, S106), and are added to the previous correction values associated therewith in the following manner:

Correction Value $D_1 = D_{11} + D_{12} + \dots$

20 Correction Value $D_2 = D_{21} + D_{22} + \dots$

Correction Value $D_3 = D_{31} + D_{32} + \dots$

Eventually, when the value of each D_{ni} (where n , i are positive integers) is equal to or less than the threshold value A (Yes at step S108), a routine for calculating the color shift correction values
25 is terminated, followed by storage of the color shift correction values D_n in the memory 121 at step S107.

[0070]

1.5.2 Correction of Color Shift During Formation of Image

Fig. 14 is a flow chart illustrating a processing procedure for
30 correcting a color shift during the formation of an image.

[0071]

After calculating the color shift correction values D_n in the foregoing manner, the color shift correction values D_n are used to

correct a color shift to form an image. Specifically, upon start of the formation of an image, the measured color shift correction values D_n are read from the memory 121 (step S201). The color shift correction value D_n at the leading end of the image is separated into a timing control correction value and a beam position correction value (step S202). The color shift correction value D_n is separated into the timing control correction value and the beam position correction value because they are separately processed by the beam position control circuit 210 and the write timing control circuit 230, respectively, of the system controller 200, as may be seen from the block diagram of Fig. 12. The separation involves dividing the amount of color shift at the leading end of the image by a value corresponding to one line interval to provide a "quotient" and a "residual." The quotient is applied to the write timing control circuit 230, while the "residual" is applied to the beam position control circuit 210. Specifically, the "quotient" is corrected by the write timing correction, while the "residual" is corrected by the beam position correction. The reason for employing such a separate correction strategy lies in that a long time is required to force the motor 70 to largely move the beam position, whereas a large amount of color shift may be instantaneously corrected when the timing is controlled.

[0072]

After the color shift correction values are processed in the foregoing manner, the system controller 200 executes a beam position correction control and a write timing correction control. The correction controls cause a write to start at a corrected write position to form an image (step S203). Since the amount of color shift gradually changes without any sudden change after the leading end of the image, the color shift is subsequently corrected by adjusting the beam position to form the image (step S203). In this way, the color shift correction value may be separated at the leading end of the image, and the image may be formed at the corrected write position from the detection of the reference position on the photoconductor drum 10,

so that after that time, the color shift is corrected from the leading end of the image to carry out the formation of the image.

[0073]

As illustrated in Fig. 12, in the beam position control, the beam
5 position control circuit 210 outputs a signal corresponding to a
displacement amount required for a correction, based on the color shift
amount correction value D_n , to the beam position moving motor 70 shown
in Fig. 7 to rotate the motor 70. As the LD unit 61 is rotated about
the center of rotation 61f, the optical axis 61g of the laser beam
10 L is displaced as shown in Fig. 6, while the beam irradiation position
is displaced on the photoconductor surface 10a as shown in Fig. 8.
In the first embodiment, a stepping motor with 20 pulses per rotation
has been used for the beam position moving motor 70, and measurements
have been made for the rotating angle of the LD unit 61, and the beam
15 irradiation position on the photoconductor surface 10. The result
of the measurement shows that the beam position on the photoconductor
surface 10a is displaced by $40\text{ }\mu\text{m}$ per rotation (about $2\text{ }\mu\text{m}$ per pulse),
i.e., the beam position may be highly accurately controlled.
Specifically, since the dot pitch is about $21\text{ }\mu\text{m}$ when the writing
20 density is 1,200, the color shift may be corrected with the accuracy
of one tenth of the dot pitch.

[0074]

As illustrated in Fig. 8, the LD unit 61 is rotated to cause the
position of the laser beam L to be displaced in the main scanning
25 direction as well in the first embodiment. However, the amount of
displacement in the main scanning direction is sufficiently smaller
than that in the sub-scanning direction. Also, since the writing is
synchronized in the main scanning direction by the synchronization
sensor 64, the displacement in the main scanning direction does not
30 incur any problem.

[0075]

1.5.3 Details on Registration Control

Next, a detailed description is made on the registration of each

color image performed in the color laser printer 1 according to the first embodiment.

[0076]

In the color laser printer 1, the image generator block 2 writes
5 the color shift detection pattern PN for the respective colors on the Y-, C-, M-, K- photoconductor drums 10Y, 10C, 10M, 10K by the exposure unit 6, and forms the developed color shift detection patterns PN for the respective colors Y, C, M, K onto the intermediate transfer belt 11, as illustrated in Fig. 10. The color shift detection pattern PN
10 for each color is formed out of a region of the intermediate transfer belt 11 on which a transfer sheet is conveyed. The respective color shift detection patterns PN are formed in a direction indicated by an arrow, in which the intermediate transfer belt 11 is conveyed, in the order of K, M, C, Y, with reference to the black K in respective
15 times t1, t2, t3, resulting in the formation of a linear pattern which extends with the aforementioned time intervals in a direction substantially orthogonal to the direction in which the intermediate transfer belt 11 is conveyed. Each color shift detection pattern PN is optically sensed by the color shift sensor 38 in sequence when it
20 passes below the color shift sensor 38, associated with the movement of the intermediate transfer belt 11 in a direction indicated by an arrow, and is counted by the counter 140Y, 140M, or 140C on a color-by-color basis. The counted values are applied to the color shift amount calculation circuit 110 which compares the times t1, t2, t3, at which the associated color shift detection patterns PN are
25 written, with the times at which they are detected, with reference to the black K, to calculate the amount of shift between the respective colors in the sub-scanning direction.

[0077]

30 The counters 140Y, 140M, 140C are all reset by a K sensing signal to start counting. Then, the counter 140C, for example, stops counting in response to a C sensing signal. Likewise, the other counters 140M, 140Y stop counting in response to M and Y sensing signals,

respectively. Since the subsequent circuits also operate in a similar manner for the colors Y, M, C, the following description is made only on those associated with the color C as a representative. As described above, in the first embodiment, each color image is registered with
5 reference to the position of the pattern PN for the black K, and the difference between set values TKC, KCsM is calculated by:

$$\Delta TC = KCM - KCsM$$

where M is the clock frequency of the counter (Hz), KC is an actual count value, and KCs is the set count value. The resulting ΔTC
10 represents the amount of shift of the spacing between the K- color shift detection pattern and C-color shift detection pattern to the set spacing.

[0078]

The polygon mirror 62 illustrated in Fig. 6 has, for example, six
15 polygon surfaces 62b which provide reflective surfaces. Therefore, for rotating the polygon mirror at 20,000 rpm to form an image at a pixel density of 600 dpi with a single beam LD 61a, the line velocity V1 of the photoconductor drum 10 is to be set to 84.67 mm/s to form an image. If the image is written using two beams, the line velocity
20 of the photoconductor drum 10 is increased to 169.33 mm/s. Here, if the amount of shift ΔTC of the spacing between the K- and C-color shift detection patterns PN to the set spacing is calculated to be 4.8 ms, a beam irradiation position adjusting value ΔX is calculated as follows:

$$\begin{aligned} 25 \quad \Delta X &= \Delta TC \times V1 \\ &= 4.8 \text{ ms} \times 84.67 \text{ mm/s} \\ &= 0.406 \text{ mm} \end{aligned}$$

Based on the calculated value, the beam position control circuit
210 drives the motor 70 for displacing the optical axis 61g of the
30 laser beam to displace the position on the photoconductor drum 10 to which the laser beam is irradiated in the sub-scanning direction by 0.406 mm, thereby correcting the amount of shift. Similarly, for the M- and Y-color shift detection patterns PN, the amounts of shifts ΔTM ,

ΔTY are calculated, and the optical axis 61g of the laser beam is displaced in accordance with the calculated amounts of shifts to correct the amounts of shifts.

[0079]

5 By thus controlling the beam position, the laser beam printer 1 may strictly correct the amount of misregistration even if the respective polygon mirrors 62 do not match in the rotation phase. Though not shown, such a correction may be applied as well to a color image forming apparatus which employs a single LD unit and an optical
10 deflector to write images in respective colors, thereby providing for strict registration.

[0080]

As described above, according to the first embodiment, the color shift detection patterns PN are written before the formation of an
15 image, the developed color shift detection patterns are read, and the beam position moving motor 70 is rotated based on beam position correction data from the read color shift detection patterns PN during the formation of a latent image to correct a write position for a color image which is detected to have a color shift in the sub-scanning
20 direction. Consequently, the misregistration may be corrected with a high accuracy.

[0081]

2. Second Embodiment

2.1 General Configuration and Control Scheme of Image Forming 25 Apparatus

In a second embodiment, a photoconductor drum reference position mark 23 is attached on one of the photoconductor drums 10 in the first embodiment, as shown in Fig. 15, and a reference position sensor 24 is provided for detecting the photoconductor drum reference position
30 mark 23 to correct a color shift. Thus, the second embodiment differs from the first embodiment in that the beam position is controlled based on the photoconductor drum reference position mark 23 and the output of the reference position sensor 24. Since the rest of the

configuration in the second embodiment is equivalent to that of the first embodiment, like parts are designated the same reference numerals, and repeated description thereon is omitted.

[0082]

5 Fig. 15 generally illustrates a configuration of a driving mechanism for rotating the photoconductor drums 10Y, 10C, 10M, 10K and the intermediate transfer belt 11 in the image generator block 2 according to the second embodiment. As may be seen from Fig. 15, the photoconductor drum reference position mark 23 is provided on the
10 photoconductor drum gear 21C for driving the photoconductor drum 10C for cyan C, and the photoconductor drum reference position sensor 24 is provided in the housing of the image generator block 2, in the driving mechanism according to the first embodiment illustrated in Fig. 9. Also, as illustrated in a block diagram of Fig. 17 which
15 depicts the configuration for controlling a misregistration correction, the photoconductor drum reference position sensor 24 is provided. The photoconductor drum reference position sensor 24 is controlled by the sensor control circuit 130, and the output of the sensor 24 is applied to the sensor control circuit 130 for conducting
20 a control operation as illustrated in Figs. 18 and 19.

[0083]

The block diagram illustrated in Fig. 17 additionally includes only the photoconductor drum reference position sensor 24 in the configuration for controlling a misregistration correction
25 illustrated in Fig. 12 in the first embodiment, so that like parts are designated the same reference numerals, and repeated description thereon is omitted.

[0084]

As illustrated in Fig. 15, when the respective photoconductor drums
30 10Y, 10C, 10M, 10K are coupled to the photoconductor drum gears 21Y, 21C, 21M, 21K, respectively, by the coupling gears 22a, 22b, the respective photosensitive gears 21Y, 21C, 21M, 21K do not shift in phase from an initial state in which the gears are assembled, so that

the reference position mark 23 is provided on any predetermined one of the photoconductor drums 10Y, 10C, 10M, 10K or photoconductor drum gears 21Y, 21C, 21M, 21K, and the photoconductor drum reference position sensor 24 is provided for detecting the reference position mark 23, to detect the rotation phase of the drums. Alternatively, when the respective photoconductor drums 10Y, 10C, 10M, 10K are driven by independent motors instead of the configuration as illustrated in the second embodiment, the reference position marks 23 may be provided on the respective photoconductor drums 10Y, 10C, 10M, 10K or photoconductor drum gears 21Y, 21C, 21M, 21K, and associated reference position sensors 24 may be provided for detecting the rotation phases of the associated photoconductor drums to detect the rotation phases of the respective photoconductor drums.

[0085]

As mentioned above, the rotational speed of the photoconductor drums may fluctuate due to uneven rotation of the driving motor 19, accumulated pitch errors and eccentricity of the driving motor gear 20, accumulated pitch errors and eccentricity of the photoconductor drum gear 21, accumulated pitch errors and eccentricities of the rotation coupling (idler) gears 22a, 22b, and the like. While the second embodiment is described in connection with the gear driving mechanism, the same applies to a driving mechanism which is implemented by pulleys. In this way, the rotational speed of the photoconductor drum 10 fluctuates due to the respective driving elements, resulting in an AC color shift which fluctuates on a periodic basis.

[0086]

In view of the foregoing, in the second embodiment, a rotating angle θ from the exposure position to the transfer position, and rotational speed of the driving elements are related in the following manner in order to reduce the AC color shift due to fluctuations in the rotational speed of the photoconductor drums 10:

(1) Transfer Position Interval: Integer Multiple of Distance from Exposure Position to Transfer Position;

(2) Rotating Angle θ from Exposure Position to Transfer Position;
the motors rotate an integer number; and

(3) Rotating Angle θ from Exposure Position to Transfer Position;
the idlers rotate an integer number.

5 When the three conditions mentioned above are satisfied, the uneven
rotation of the drum driving motor 19 in one rotation and fluctuations
in speed of the motor gear 20 and idler gears 22a, 22b do not lead
to a color shift because the components are driven at the same period
and synchronized with one another from the exposure to the transfer.
10 However, the photoconductor drum gear 21 may not be synchronized with
the remaining components because of its period longer than the period
from the exposure to the transfer, causing the AC color shift. While
the AC color shift may be eliminated only by driving the photoconductor
drum gears 21Y, 21C, 21M, 21K at the same phase and amplitude, it may
15 not be actually said that they are driven over the same amplitude.
In effect, an AC color shift occurs as illustrated in Fig. 16.

[0087]

Fig. 16 is a graph which shows the result of a measurement of an
AC color shift made by the color shift sensor 38 with the color shift
20 detection pattern PN which is formed on the intermediate transfer belt
11 at the time the photoconductor drum reference position sensor 24
detects the photoconductor drum reference position mark 23. The graph
shows the amount of shift of a cyan image C with reference to a black
image K. In this way, a color shift occurs due to fluctuations in
25 the period of one rotation of the photoconductor drum 10, and a DC
color shift (20 μm in Fig. 16) may be superimposed on the AC color
shift.

[0088]

2.2 Calculation of Color Shift Value

30 Fig. 18 is a flow chart illustrating the processing procedure for
calculating a color shift correction value according to the second
embodiment.

[0089]

The illustrated routine includes step S120 at which the photoconductor drum reference position is detected, between steps S101 and S102 in the flow chart of Fig. 13 in the first embodiment. At the time the photoconductor drum reference position sensor 24 detects the photoconductor drum reference position mark 23 (or with reference to the time), the color shift correction pattern PN is written (step S102), such that the color shift sensor 38 detects the color shift correction pattern PN to calculate a color shift correction value. Since the respective processing steps except for step S120 are identical to those in the first embodiment, repeated description thereon is omitted.

[0090]

2.3 Correction of Color Shift During the Formation of Image

Fig. 19 is a flow chart illustrating a processing procedure for correcting a color shift in the second embodiment. The flow chart includes step S210 at which the photoconductor drum reference position is detected, between steps S202 and S203 in the flow chart of Fig. 14 in the first embodiment. The remaining processing steps are similar to those in the first embodiment. Specifically, after calculating the color shift correction value D_n as described above, the color shift correction value D_n is used to correct a color shift, followed by the formation of an image. As described above, in the second embodiment, the photoconductor drum reference position sensor 24 detects the photoconductor drum reference position mark 23, and the color shift correction value is calculated at the time the photoconductor drum reference position mark is detected. In other words, with reference to the detected photoconductor drum reference position, so that the image is written with reference to the timing at which the photoconductor drum reference position is detected even when a color shift is corrected.

[0091]

Specifically, upon start of the formation of an image, the measured color shift correction values D_n are read from the memory 121 (step S201), and the color shift correction value D_n at the leading end of

the image is separated into a timing control correction value and a beam position correction value (step S202). Then, the sensor control circuit 130 detects a reference position of the photoconductor drum 10C based on the detection output of the photoconductor drum reference position sensor 24 (step S210), and image writing is started based on the color shift correction value found by the routine of Fig. 18, thus forming the image (step S203). Since the amount of color shift after the leading end of the image smoothly changes without any sudden change, the color shift is subsequently corrected by adjusting the beam position to form the image. In this way, since the color shift correction value at the leading end of the image may be separated, and the image may be formed at a corrected image position from the time the reference position is detected on the photoconductor drum 10, so that the image is formed while the color shift is corrected from the leading end of the image after that time.

[0092]

As described above, according to the second embodiment, a color shift may be corrected with a high accuracy because the reference position is detected on the photoconductor drum 10, and the color shift correction pattern PN formed based on the reference position of the photoconductor drum 10 is detected to correct the color shift at the time a latent image is written.

[0093]

Otherwise, the respective components and processing, which are not particularly described, are similar in configuration and function to their counterparts in the first embodiment.

[0094]

3. Third Embodiment

3.1 General Configuration and Control Scheme of Image Forming Apparatus

As illustrated in Fig. 20, in a third embodiment, a belt reference position mark 40 is provided on the intermediate transfer belt 11, and a belt reference position sensor 39 is provided for detecting the

belt reference position mark 40 to correct a color shift. Except for the control based on the belt reference position mark 40 and the output of the belt reference position sensor 39, the third embodiment is similar to the first embodiment in the remaining configuration, so
5 that like parts are designated the same reference numerals, and repeated description thereon is omitted.

[0095]

Fig. 20 generally illustrates the structure of a driving mechanism for rotating the photoconductor drums 10Y, 10C, 10M, 10K and
10 intermediate transfer belt 11 in the image generator block 2 according to the third embodiment. As may be seen from Fig. 20, in addition to the driving mechanism illustrated in Fig. 9 in the first embodiment, the belt reference position mark 40 is provided on the intermediate transfer belt 11, and the belt reference position sensor 39 is provided
15 in the housing of the image generator block 2. Also, as illustrated in a block diagram of Fig. 22 which depicts the configuration for controlling a misregistration correction, the belt reference position sensor 39 is provided. The belt reference position sensor 39 is controlled by the sensor control circuit 130, and the output of the
20 belt reference position sensor 39 is applied to the sensor control circuit 130 for conducting the control as illustrated in Figs. 23 and 24.

[0096]

The block diagram illustrated in Fig. 22 additionally includes only
25 the belt reference position sensor 39 in the configuration for controlling a misregistration correction illustrated in Fig. 12 in the first embodiment, so that like parts are designated the same reference numerals, and repeated description thereon is omitted.

[0097]

30 As described above, in the relationship between the rotating angle θ from the exposure position to the transfer position, and the rotational speed of the driving elements, the following conditions are set in order to reduce the AC color shift due to fluctuations in

the rotational speed of the photoconductor drums 10:

(1) Transfer Position Interval: Integer Multiple of Distance from Exposure Position to Transfer Position;

(2) Rotating Angle θ from Exposure Position to Transfer Position;
5 the motors rotate an integer number; and

(3) Rotating Angle θ from Exposure Position to Transfer Position;
the idlers rotate an integer number.

When the three conditions mentioned above are satisfied, the uneven
rotation of the drum driving motor 19 in one rotation and fluctuations
10 in speed of the motor gear 20 and idler gears 22a, 22b do not lead
to a color shift because the components are driven at the same period
and synchronized with one another from the exposure to the transfer.
However, the photoconductor drum gear 21 may not be synchronized with
the remaining components because of its period longer than the period
15 from the exposure to the transfer, causing the AC color shift. However,
the AC color shift may be eliminated if the photoconductor drum gears
21Y, 21C, 21M, 21K are composed of the same parts and driven at the
same phase and amplitude.

[0098]

20 On the other hand, the intermediate transfer belt 11 or a transfer
conveyance belt is driven by a driving force of the belt driving motor
which is transmitted through the timing belt 32 wrapped around the
motor pulley 31 on the driving shaft of the belt driving motor 30 and
the driving pulley 33 on the shaft of the belt driving roller 34. As
25 mentioned above, the belt reference position mark 40 is provided on
the intermediate transfer belt 11 for determining the rotation phase
of the intermediate transfer belt 11. The belt reference position
sensor 39 provided in the housing detects the rotation phase of the
intermediate transfer belt 11. Here, the rotational speed of the
30 intermediate transfer belt 11 may fluctuate due to uneven rotation
of the belt driving motor 30, eccentricity of the motor pulley 31,
eccentricity of the pulley 33 of the belt driving roller 34,
eccentricity of the driving roller 34, uneven belt thickness, and the

like. In the third embodiment, each image formation station pitch L and each driving element are related in the following manner to prevent a color shift.

[0099]

5 (4) Each Image Formation Station Pitch $P = \text{Perimeter of Belt Driving Roller Multiplied by Integer}$; and

 (5) Each Image Formation Station Pitch $P = \text{Rotational Speed of Belt Driving Motor Multiplied by Integer}$.

 When the above conditions are satisfied, the uneven rotation of
10 the belt driving motor 30 in one rotation and fluctuations in speed of the respective pulleys 31, 33 and belt driving roller 34 do not lead to a color shift because the components are driven at the same period and synchronized with one another between the respective image formation stations. It is to be noted that the image formation station
15 pitch P is shown in Fig. 9.

[0100]

 Fig. 21 is a graph which shows the result of a measurement of an AC color shift made by the color shift sensor 38 with the color shift detection pattern which is formed at the time the belt reference
20 position sensor 39 detects the belt reference position mark 40. In the third embodiment, the graph shows the amount of shift of a cyan image C with reference to a black image K. It may be seen in the graph that a color shift occurs due to fluctuations in the period of one rotation of the intermediate transfer belt 11. A DC color shift may
25 sometimes be superimposed on the AC color shift.

[0101]

3.2 AC Color Shift due to Uneven Belt Thickness

 A so-called belt element such as a transfer material conveying belt, an intermediate transfer belt and the like has been conventionally
30 made of a sheet material which is joined end to end to form an endless form. However, since no image may be formed at the joint of the belt, a so-called seamless belt element has been increasingly employed from a view point of an improved productivity of image formation. For

example, a belt element manufactured by a so-called centrifugal molding method which involves casting and sintering a raw material solution in a rotary mold is susceptible to an uneven thickness in the circumferential direction of the belt element due to limitations
5 inherent in the manufacturing method. Such an uneven thickness does not repeat increases and decreases in thickness, but often appears in a sinusoidal wave in one turn in the circumferential direction.

[0102]

When a belt having such an uneven thickness is employed in a transfer
10 belt of a tandem type image forming apparatus, the distance extending over the image forming units is calculated by $N \times \pi \times (D+T)$, where D is the diameter (mm) of a driving roller for driving the belt, T is the thickness of the belt (mm), V is the image forming speed (mm/sec), D+T is the diameter of the neutral surface of the belt (diameter of
15 a pitch circle) (mm), and N is an integer. Therefore, for reducing the apparatus to the smallest possible size, the distance extending over image forming units is calculated by: $\pi \times (D+T)$ (mm)

[0103]

The amount of fluctuations in the image forming speed is calculated
20 by:

$$(\Delta T)/(T+D) \times V \text{ (mm/sec)} \dots (1)$$

where ΔT is a difference in the thickness of the belt.

[0104]

Generally, a full color image is formed by four image forming units,
25 the distance between the image forming units at the extreme ends is calculated by $3 \times \pi \times (D+T)$ (mm). At a normal image forming speed, a time required for a sheet to pass through the four image forming units is calculated by: $3 \times \pi \times (D+T) / V$ (seconds) ... (2)

[0105]

Therefore, the amount of misregistration on an image, which may
30 occur if the roller is worn away, is found between the extreme image forming units, by multiplying the equation (1) by the equation (2):
 $3 \times \pi \times (\Delta T) \dots (3)$

[0106]

Specifically, even if there is 10 μm of difference in the belt thickness, the amount of color shift mounts up to approximately 94 μm , as calculated from the equation (3). It is understood from the fact that a shift exceeding two pixels, when the resolution is 600 dpi, is repeated every cycle of the belt, resulting in the AC color shift (see Fig. 21).

[0107]

3.3 Calculation of Color Shift Correction Value

Fig. 23 is a flow chart illustrating a processing procedure for calculating a color shift correction value according to the third embodiment.

[0108]

The flow chart includes step S130 at which the belt reference position is detected, between steps S101 and S102 in the flow chart of Fig. 13 in the first embodiment. Specifically, at step S130, at the time the belt reference position sensor 39 detects the belt reference position mark 40 (or with reference to the time), the color shift correction pattern PN is written (step S102). The color shift sensor 38 detects the color shift correction pattern PN to calculate a color shift correction value. Since the processing steps in Fig. 23 except for step S130 is identical to those in the first embodiment, repeated description thereon is omitted.

[0109]

3.4 Correction of Color Shift during Formation of Image

Fig. 24 is a flow chart illustrating a processing procedure for correcting a color shift in the third embodiment. The flow chart includes step S220 at which the belt reference position is detected, between steps S202 and S203 in the flow chart of Fig. 14 in the first embodiment. The remaining processing steps are similar to those in the first embodiment. Specifically, after calculating the color shift correction value D_n as described above, the color shift correction value is used to correct a color shift, followed by the

formation of an image. As described above, in the third embodiment, the belt reference position sensor 39 detects the belt reference position mark 40, and the color shift correction value is calculated at the time the belt reference position mark is detected, in other
5 words, with reference to the detected belt reference position, so that the image is written with reference to the timing at which the belt reference position is detected even when a color shift is corrected.

[0110]

Specifically, upon start of the formation of an image, the measured
10 color shift correction value Dn is read from the memory 121 (step S201), and the color shift correction value Dn at the leading end of the image is separated into a timing control correction value and a beam position correction value (step S202). Then, the sensor control circuit 130 detects a reference position of the intermediate transfer belt 11 based
15 on the detection output of the belt reference position sensor 39 (step S220), and image writing is started based on the color shift correction value found by the routine of Fig. 23, thus forming the image (step S203). Since the amount of color shift after the leading end of the image smoothly varies without any sudden change, the color shift is
20 subsequently corrected by adjusting the beam position to form the image. In this way, since the color shift correction value at the leading end of the image may be separated into the timing control correction value and beam position correction value, and the image may be formed at a corrected image position from the time the reference position
25 is detected on the photoconductor drum 10, so that the image is formed while the color shift is corrected from the leading end of the image after that time.

[0111]

As described above, the separation at step 202 involves dividing
30 the amount of color shift at the leading end of the image by a value corresponding to one line interval to provide a "quotient" and a "residual." The quotient is applied to the write timing control circuit 230, while the "residual" is applied to the beam position

control circuit 210. Specifically, the "quotient" is corrected by the write timing correction, while the "residual" is corrected by the beam position correction. To give a specific example, when the color shift correction value D_n is separated in the example shown in Fig.

5 21, the dot pitch is approximately $42\text{ }\mu\text{m}$ when the resolution (writing density) is 600 dpi, so that $150\text{ }\mu\text{m}$ is divided by the dot pitch of $42\text{ }\mu\text{m}$:

$$150\text{ }\mu\text{m} / 42\text{ }\mu\text{m} = 3 \text{ with residual of } 24$$

Thus, $126\text{ }\mu\text{m}$ corresponding to three dots are processed by the timing
10 control circuit 230, while the residual of $24\text{ }\mu\text{m}$ is processed by the beam position control circuit 210, wherein the former modulates the LD 61b, and the latter drives the beam position moving motor 70 to correct a color shift. Twenty-four ($24\text{ }\mu\text{m}$) corresponds to 12 steps of the beam position moving motor. By thus conducting the timing
15 control and beam position control in parallel, the writing position may be rapidly corrected with a high accuracy.

[0112]

As described above, according to the third embodiment, a color shift may be corrected with a high accuracy because the reference position
20 is detected on the intermediate transfer belt 11, and the color shift correction pattern PN formed based on the reference position of the intermediate transfer belt 11 is detected to correct the color shift at the time a latent image is written.

[0113]

25 Otherwise, the respective components and processing, which are not particularly described, are similar in configuration and function to their counterparts in the first embodiment.

[0114]

4. Fourth Embodiment

30 In a fourth embodiment, the beam irradiation position adjusting mechanism in the first to third embodiments is replaced from a rotary mechanism to a translational mechanism. The remaining components are similar in configuration to their counterparts in the first to third

embodiments, so that repeated description thereon is omitted.

[0115]

Figs. 25 to 27 are diagrams for describing the fourth embodiment. Specifically, Fig. 25 is a front view illustrating a main portion of an LD unit as well as a supporting mechanism and a moving mechanism associated therewith; Fig. 26 shows a position on a photoconductor surface which is irradiated with a laser beam; and Fig. 27 is a side view of a pair of guide rails which form part of the supporting mechanism. As illustrated in Fig. 25, the LD unit 61' according to the fourth embodiment includes a pair of parallel guide rails 61h extending in the sub-scanning direction (vertical direction in Fig. 25), instead of along the axis of rotation 61f shown in Fig. 7, for supporting the holding member 61d for movement in the sub-scanning direction. In the configuration, the arm 61e is also driven by the beam position moving motor 70. The LD unit 61' translates in the sub-scanning direction along the guide rails 61h in response to the rotation of the beam position moving motor 70. In the fourth embodiment, the LD unit 61' translates in a similar manner such that an irradiation position matches on the mirror surface 62b of the polygonmirror 62, as shown in Fig. 5B described above. For this reason, the parallel rails 61h are formed with a curvature R as illustrated in Fig. 27 such that the parallel rails 61h move along an arc about the matching point on the mirror surface 62b.

[0116]

Also, while the lead screw 71 is engaged with the female thread 61i formed in the arm 61e, and driven by the beam position moving motor 70 also in the fourth embodiment, the arm 61e may be removed, in which case a central portion of the holding member 61d (between the parallel rails 61h) is driven. In other words, as long as the posture of the holding member 61d is restricted by the parallel rails 61h, the translation is possible irrespective of the position at which the lead screw 71 is engaged or meshed.

[0117]

Otherwise, the respective components and processing, which are not particularly described, are similar in configuration and function to their counterparts in the first to third embodiments.

[0118]

5 While the first to fourth embodiments have illustrated tandem type color printers (including copiers), the present invention may be applied as well to a monochrome (black and white) image forming apparatus for reducing a scaling error deviation in the sub- scanning direction.

10 [0119]

5. Other Embodiments

As previously mentioned, other methods of correcting a color shift may include, for example, a method of displacing the return mirror 69 in the optical writing device to displace a beam irradiation position, a method of changing the angle or moving the position of the laser beam L by optics such as a glass plate, a prism or the like inserted at a location upstream of the polygon mirror 62 on which the laser beam L is incident, and the like. In addition, the beam may be deflected by an acousto-optical element, an opto-electric element, or a liquid crystal.

[0120]

(1) Fig. 28 illustrates an exemplary method of displacing or rotating the return mirror 69 shown in Fig. 4 to displace a beam irradiation position. In Fig. 28, the angle of the return mirror 69 is varied to change the position on the photoconductor drum 10 at which the light beam is irradiated. In such a configuration, a relatively long light path α permits the beam irradiation position $\Delta\beta$ to largely move with respect to a change in angle $\Delta\theta$ of the return mirror 69. Thus, the alternative exhibits good optical characteristics at a low cost, but is poor in control capabilities.

[0121]

(2) Fig. 29 illustrates an example in which a prism PRM inserted in a light path L is moved to change a position on the photoconductor

drum 10 at which the beam is irradiated. In the example, the prism PRM is moved in a direction orthogonal to the light path L to change the beam irradiation position. When the light beam is incident on an oblique side of the triangular prism PRM and exits from a surface perpendicular to the light path L, a movement of the prism PRM upward in Fig. 29 causes the light beam to move downward, as indicated by dotted lines.

[0122]

(3) Fig. 30 illustrates an example in which a glass plate GRS is inserted in the light path L, and the angle of the glass plate GRS to the light path L is varied to change a position on the photoconductor drum 10 at which the beam is irradiated. In the example, as the angle of the glass plate GRS to the light path L is made larger, the beam is moved in a slanted direction with larger angle (in a downward direction in the drawing), as indicated by a dotted line in Fig. 30.

[0123]

When an optic part is inserted into the light path L to move the beam, the light path is changed by changing the length of the light path which passes through the glass, so that the beam diameter may be affected, and the prism entails an additional cost, though high controllability is provided.

[0124]

(4) Fig. 31 illustrates an example in which an acousto-optical element SOE inserted in the light path L is driven by a drive control circuit SOEC with high harmonics to change a beam irradiation position. The acousto-optical element SOE includes a comb-shaped electrode vapor-deposited on LiNbO_3 which relies on the light diffraction phenomenon to deflect, and drives with high harmonics. While the example is suitable for a rapid position control, the cost is inevitably increased. Alternatively, an opto-electric element or a liquid crystal may be used to deflect the beam instead of the acoustic-optical element SOE. The opto-electric element relies on a photoelastic effect to deflect a beam, while the liquid crystal

relies on the light diffraction phenomenon to deflect a beam. While both are suitable for a rapid position control as is the case with the acousto-optical element SOE, they are disadvantageous over the other examples in terms of the cost.

5 [0125]

In an image forming apparatus which irradiates a photoconductor drum with a laser beam to form an image, when a beam irradiation position is controlled to correct a color shift due to fluctuations in the rotational speed of the photoconductor drum, a belt or the like,
10 it is necessary to smoothly and slowly control the beam irradiation position in small correction increments. It is because an instantaneous large movement of the beam irradiation position causes a large change in scanning line intervals, resulting in a defective image such as blanking. From the foregoing point of view, the
15 aforementioned method (4) is not suitable for a color shift correction as proposed by the present invention, and also increases the cost. The aforementioned method (1) in turn is problematic in terms with the correction accuracy, and encounters difficulties in solving problems such as the blanking. Though presenting a good accuracy
20 control, the aforementioned methods (2), (3) may adversely affect the optical characteristics as compared with the first to fourth embodiments of the present invention, and entails a higher cost than the foregoing embodiments.

[0126]

25 As mentioned above, a color shift is caused by fluctuations in the rotational speed of the photoconductor drum or transfer belt. However, such a type of fluctuations has a periodicity and a good repeatability, so that the fluctuations in the rotational speed may be previously measured and used by the color shift amount calculation circuit 110
30 to calculate a color shift correction value which is then stored in the memory 121. When a print instruction is output, a color shift may be corrected using the stored correction value. In addition, if the stored color shift correction value may be confirmed on an

operation panel or on a printer driver and may be changed by a user or service personnel, the color shift may be corrected in a more strict way.

[0127]

5 [Effects of the Invention]

As has been described, according to the present invention, since misregistration in a sub-scanning direction of images formed of respective colors may be corrected in a same rotation phase during formation of a latent image, a color shift may be more accurately
10 corrected.

[0128]

In addition, since the color shift is corrected with high accuracy, an image may be formed in high quality.

[0129]

15 Furthermore, since both large and small scales of misregistration are simultaneously corrected in parallel through different methods, a correction may be rapidly made.

[Brief description of the Drawings]

[Fig. 1]

20 Fig. 1 is a block diagram generally illustrating a configuration of a color laser printer, which is serving as an image forming apparatus according to the first embodiment.

[Fig. 2]

Fig. 2 is a plan view illustrating an optical writing (exposure)
25 device in Fig. 1.

[Fig. 3]

Fig. 3 is a cross-sectional view generally illustrating a configuration of the optical writing (exposure) device in Fig. 1.

[Fig. 4]

30 Fig. 4 is a cross-sectional view generally illustrating the configuration of another exemplary optical writing (exposure) device in Fig. 1.

[Fig. 5]

Figs. 5A and 5B are diagrams illustrating exemplary configurations for displacing a laser beam irradiation position in a sub-scanning direction.

[Fig. 6]

5 Fig. 6 is a diagram illustrating a relationship among a LD unit, a polygon mirror, an optical axis, and a central axis of rotation.

[Fig. 7]

Fig. 7 is a front view of a beam irradiation position adjuster, when seen from one side of the LD unit from which the laser beam is
10 emitted.

[Fig. 8]

Fig. 8 is an explanatory diagram showing a beam irradiation position on a photoconductor surface when the beam position of laser beam on the photoconductor surface is displaced by the beam irradiation
15 position adjuster.

[Fig. 9]

Fig. 9 is a diagram generally illustrating a driving mechanism for rotating a photoconductor drum and intermediate transfer belt in an image generator block in the first embodiment.

20 [Fig. 10]

Fig. 10A and B are diagrams showing examples of a color shift detection pattern formed on the intermediate transfer belt.

[Fig. 11]

Fig. 11 is a graph which shows measurement results of an AC color shift made by a color shift detection sensor with a formed color shift
25 detection pattern, and shows a amount of shift in cyan images with reference to black images.

[Fig. 12]

Fig. 12 is a block diagram illustrating a configuration for
30 controlling a misregistration correction in the first embodiment.

[Fig. 13]

Fig. 13 is a flow chart showing a processing procedure for calculating a color shift correction value in the first embodiment.

[Fig. 14]

Fig. 14 is a flow chart showing a processing procedure for correcting a color shift during formation of an image in the first embodiment.

5 [Fig. 15]

Fig. 15 is a diagram generally illustrating a driving mechanism for rotating a photoconductor drum and intermediate transfer belt in an image generator block in the second embodiment.

[Fig. 16]

10 Fig. 16 is a graph which shows measurement results of an AC color shift made by the color shift detection sensor with a formed color shift detection pattern, and shows a amount of shift in cyan images with reference to black images.

[Fig. 17]

15 Fig. 17 is a block diagram illustrating a configuration for controlling a misregistration correction in the second embodiment.

[Fig. 18]

Fig. 18 is a flow chart showing a processing procedure for calculating a color shift correction value in the second embodiment.

20 [Fig. 19]

Fig. 19 is a flow chart showing a processing procedure for correcting a color shift during formation of images in the second embodiment.

[Fig. 20]

25 Fig. 20 is a diagram generally illustrating a driving mechanism for rotating a photoconductor drum and intermediate transfer belt in an image generator block in the third embodiment.

[Fig. 21]

30 Fig. 21 is a graph which shows measurement results of an AC color shift made by the color shift detection sensor with a formed color shift detection pattern, and shows a amount of shift in cyan images with reference to black images.

[Fig. 22]

Fig. 22 is a block diagram illustrating a configuration for controlling a misregistration correction in the third embodiment.

[Fig. 23]

Fig. 23 is a flow chart showing a processing procedure for
5 calculating a color shift correction value in the third embodiment.

[Fig. 24]

Fig. 24 is a flow chart showing the processing procedure for correcting a color shift during the formation of images in the second embodiment.

10 [Fig. 25]

Fig. 25 is a front view of a beam irradiation position adjuster in the fourth embodiment.

[Fig. 26]

Fig. 26 is an explanatory diagram showing a beam irradiation
15 position on a photoconductor surface when the beam position of laser beam on the photoconductor surface is displaced by the beam irradiation position adjuster in Fig. 25.

[Fig. 27]

Fig. 27 is a side view illustrating a main portion of guide rails
20 in Fig. 25.

[Fig. 28]

Fig. 28 is a diagram showing an embodiment in which a beam irradiation position relative to the photoconductor drum is changed by varying an angle of a return mirror.

25 [Fig. 29]

Fig. 29 is a diagram showing an embodiment in which a beam irradiation position relative to the photoconductor drum is changed by varying a position of a prism.

[Fig. 30]

30 Fig. 30 is a diagram showing an embodiment in which a beam irradiation position relative to the photoconductor drum is changed by varying an angle of a glass plate.

[Fig. 31]

Fig. 31 is a diagram showing an embodiment in which a beam irradiation position relative to the photoconductor drum is changed by driving an acousto-optical element with high harmonics.

[Reference Numerals]

- 5 1 Color Laser Printer (Image Forming Apparatus)
- 2 Image generator
- 5 Transfer Unit
- 6 Exposure Unit (Optical Writing Device)
- 7 Cleaning Unit
- 10 8 Charging Unit
- 9 Developing Unit
- 10, 10Y, 10C, 10M, 110K Photoconductor drum
- 10a Photoconductor surface
- 11 Intermediate Transfer Belt (Intermediate Transfer Member)
- 15 19 Drum Driving Motor
- 20 Driving Motor Gear
- 21, 21Y, 21C, 21M, 21K Photoconductor drum Gear
- 22a, 22b Rotation Coupling Gear (Idler Gear)
- 23 Photoconductor drum Reference Position Mark
- 20 24 Photoconductor drum Reference Position Detection Sensor
- 30 Belt Driving Motor
- 34 Belt Driving Motor
- 35 Pressure Roller
- 36 Driven Roller
- 25 38 Color Shift Detection Sensor
- 39 Belt Reference Position Sensor
- 40 Belt Reference Position Mark
- 61, 61Y, 61M, 61C, 61K, 61' LD Unit (Laser Light Source)
- 61a Semiconductor Laser (LD)
- 30 61b Collimator lens (Coupling Optical System)
- 61d Holding Member (Base)
- 61e Arm
- 61f Central Axis of Rotation

61g Optical Axis
 61h Guide Rail
 61i Female Thread
 62 Polygon Mirror
 5 62b Polygon Mirror Surface
 63 Focusing Optical System
 65 Aperture
 66 Cylinder Lens
 69 Mirror
 10 70 Beam Position Moving Motor
 71 Lead Screw
 100 Registration Controller
 110 Color Shift Calculation Circuit
 120 Color Shift Correction Value Processing Circuit
 15 121 Memory
 130 Sensor Control Circuit
 140, 140Y, 140M, 140C Counter
 200 System Controller
 210 Beam Position Control Circuit
 20 220 Motor Driver
 230 Write Timing Control Circuit
 240 LD Modulation Circuit
 PN Color Shift Detection Pattern

[Name of Document] Abstract of the disclosure

25 [Abstract]

 [Objectives of the Invention]

To perform correction of color shift caused by dynamic factors such
 as fluctuations in speed of an image carrier and an intermediate
 transfer element with high accuracy at a low cost without employing
 30 a driving motor rotation control means or an encoder.

 [Means for Achieving the Objectives]

In an image forming apparatus in which at least one image forming
 means having one image carrier forms images in different colors, and

the images in different colors formed by the image forming means are directly or indirectly transferred onto a movable element to form an image, a color shift among respective color images is corrected by adjusting an irradiation position of a laser beam emitted from an
5 optical writing means in a sub-scanning direction while a latent image is formed by irradiating a laser beam from the optical writing means.

[Selected Drawings] Fig. 14

FIG. 1

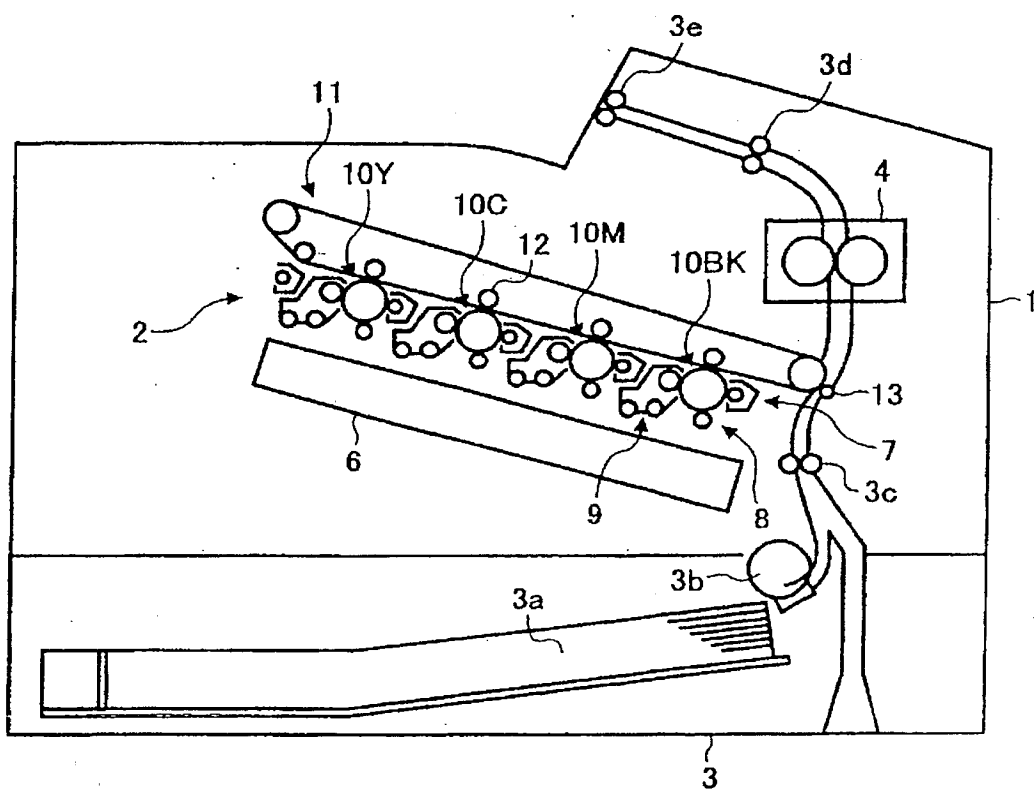


FIG. 2

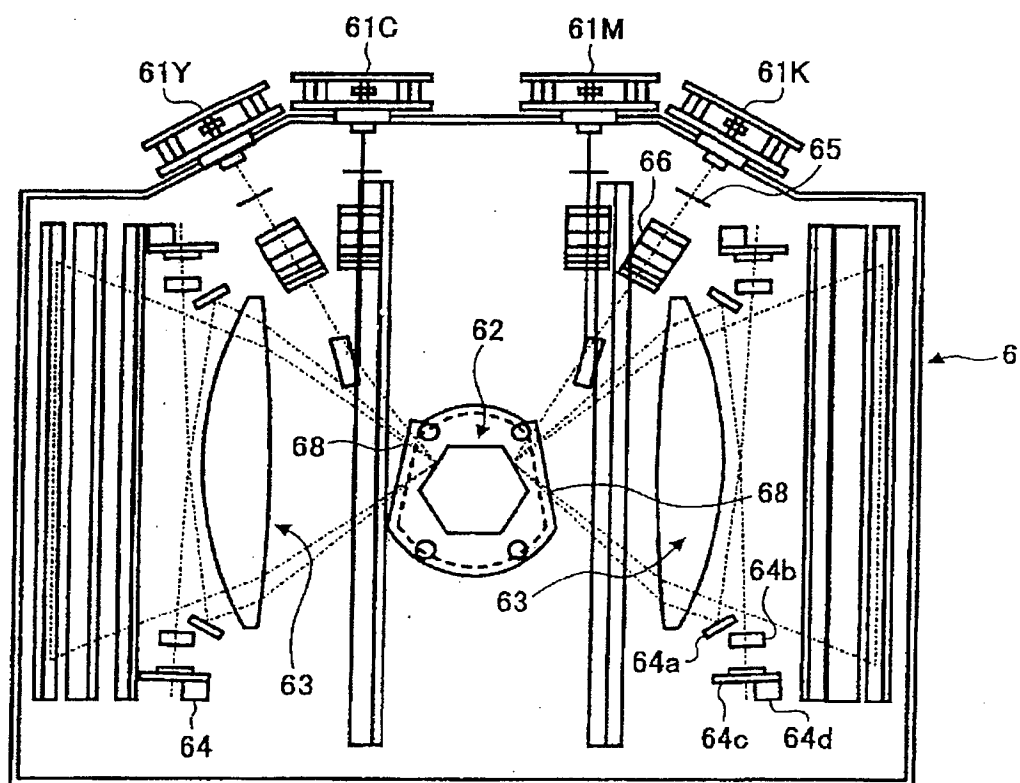


FIG. 3

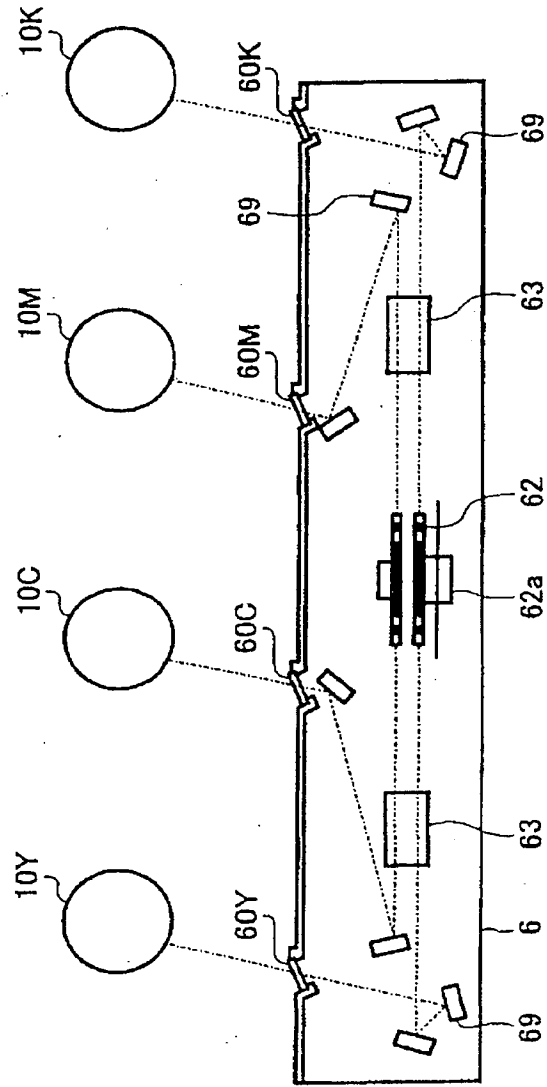


FIG. 4

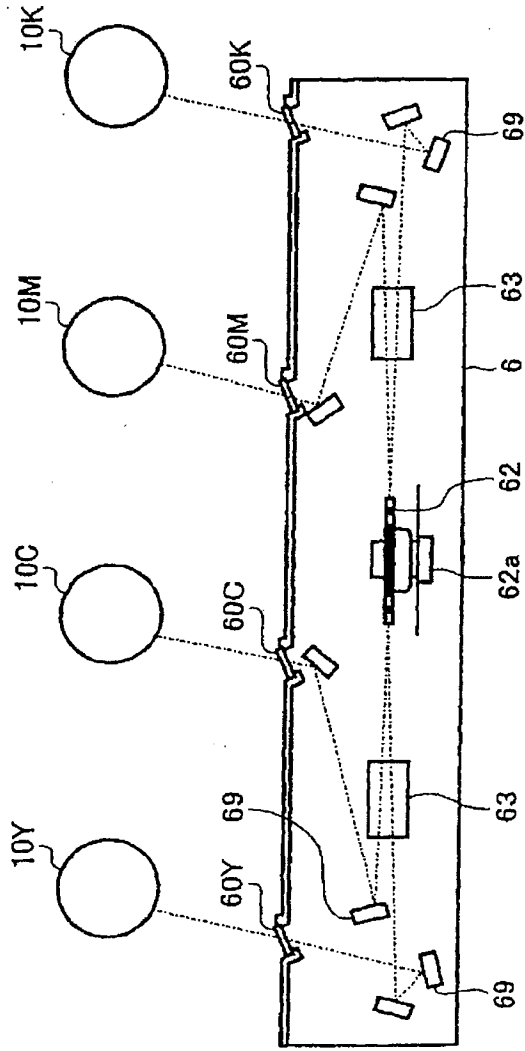


FIG. 5A

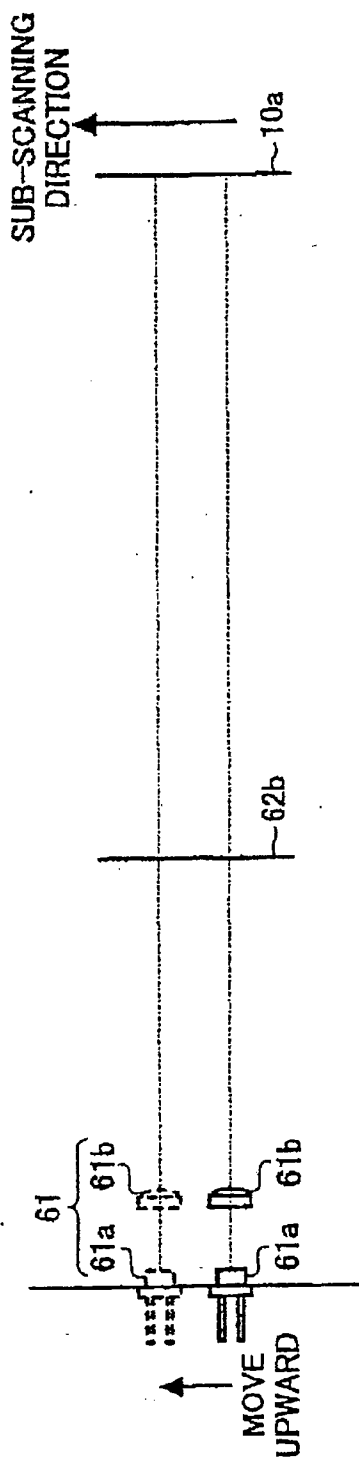


FIG. 5B

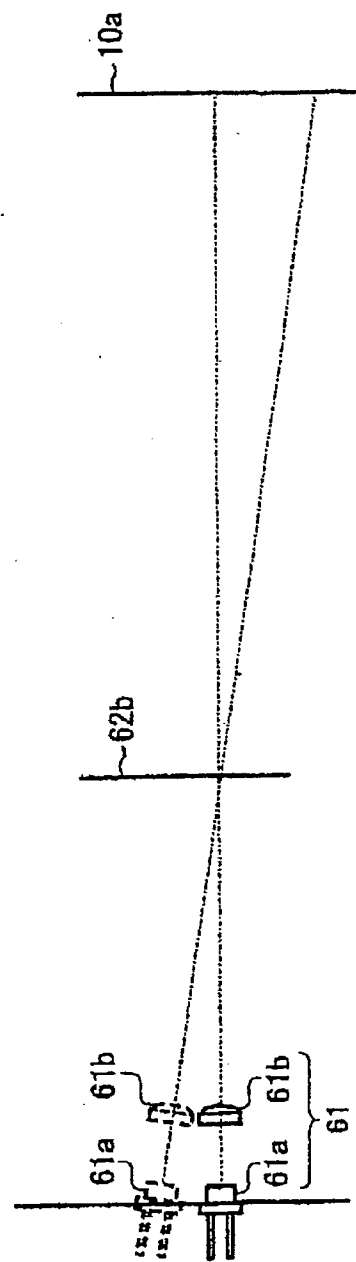


FIG. 6

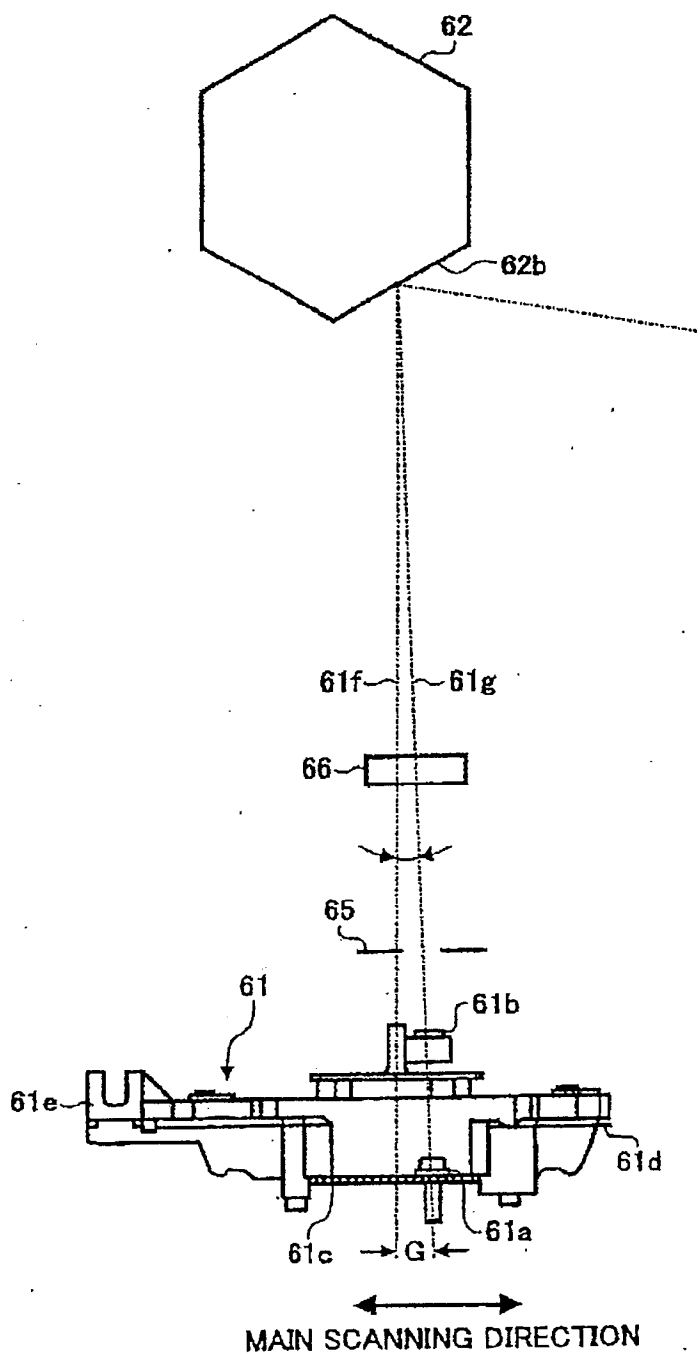


FIG. 7

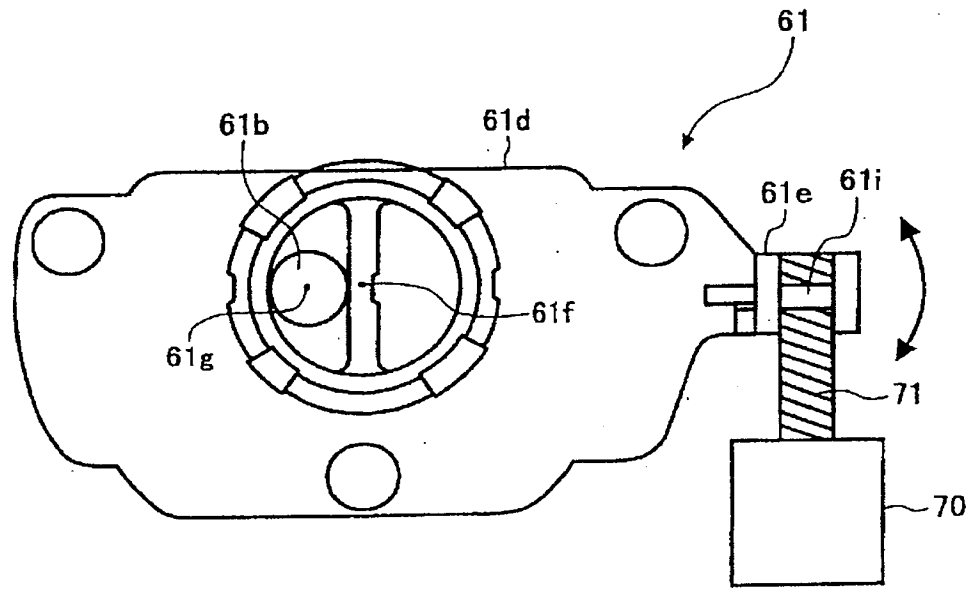
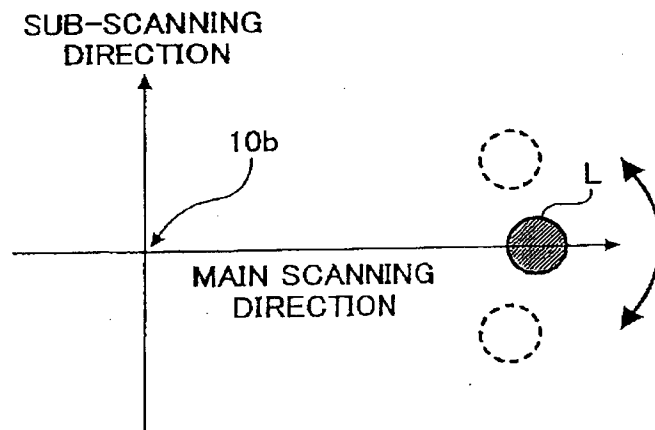


FIG. 8



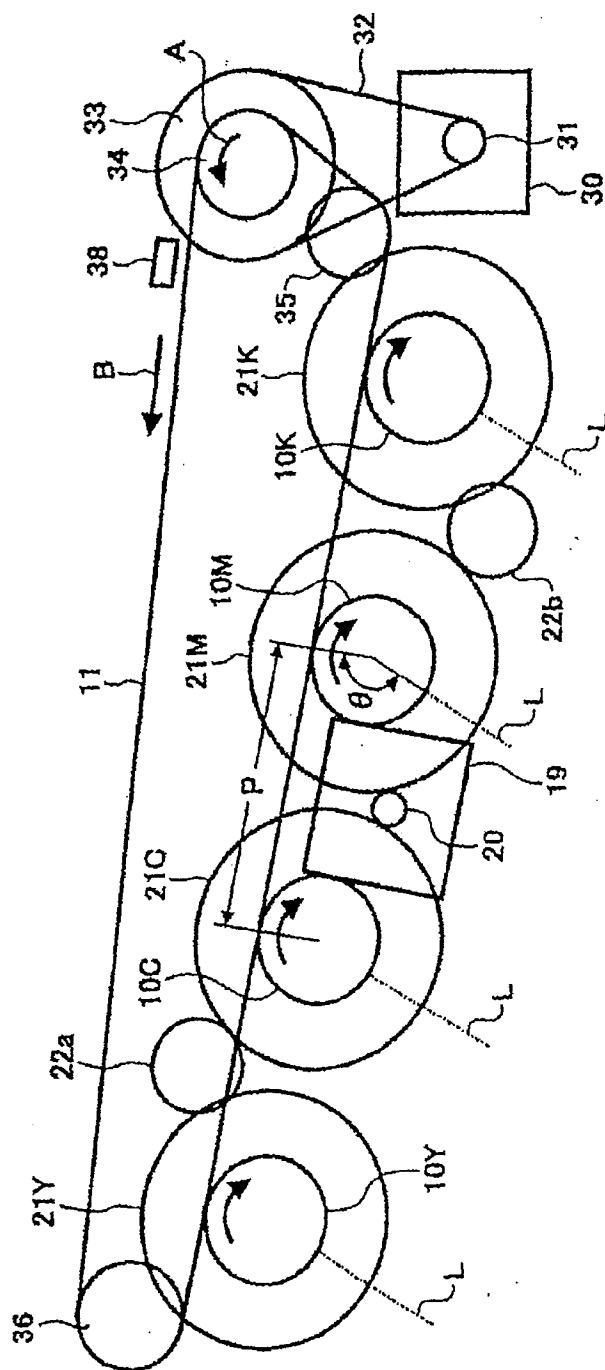


FIG. 10A

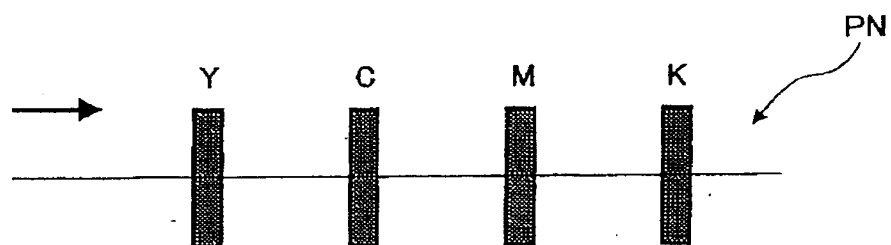


FIG. 10B

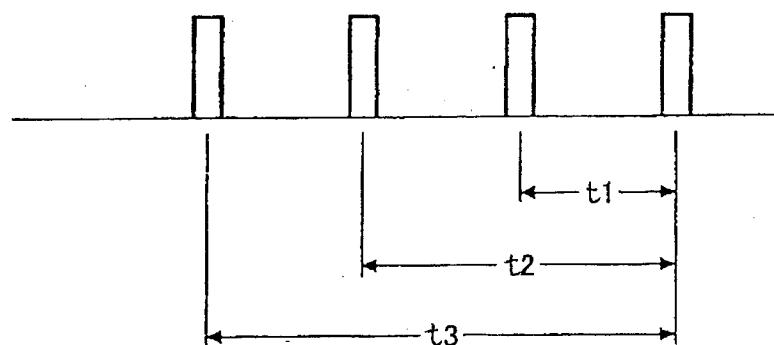


FIG. 11

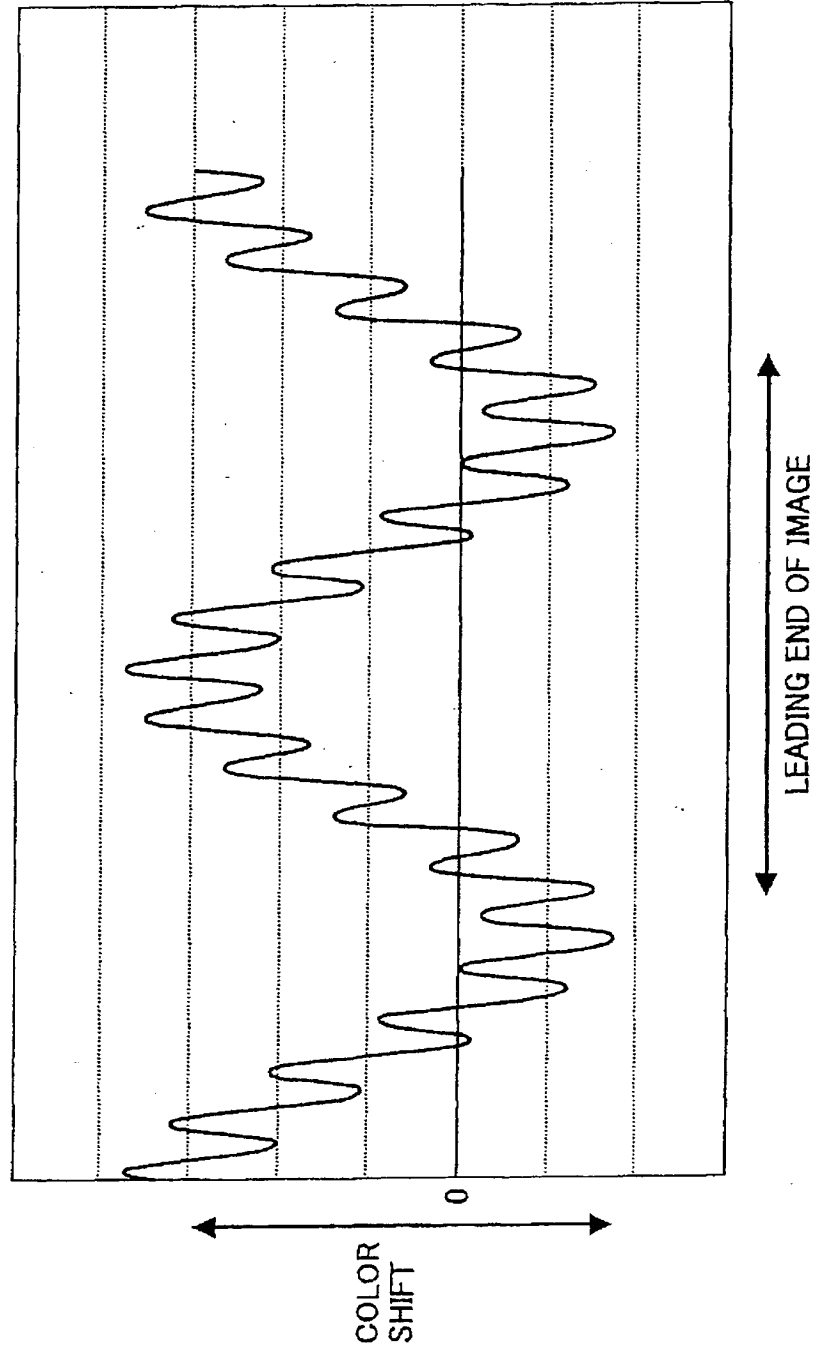


FIG. 12

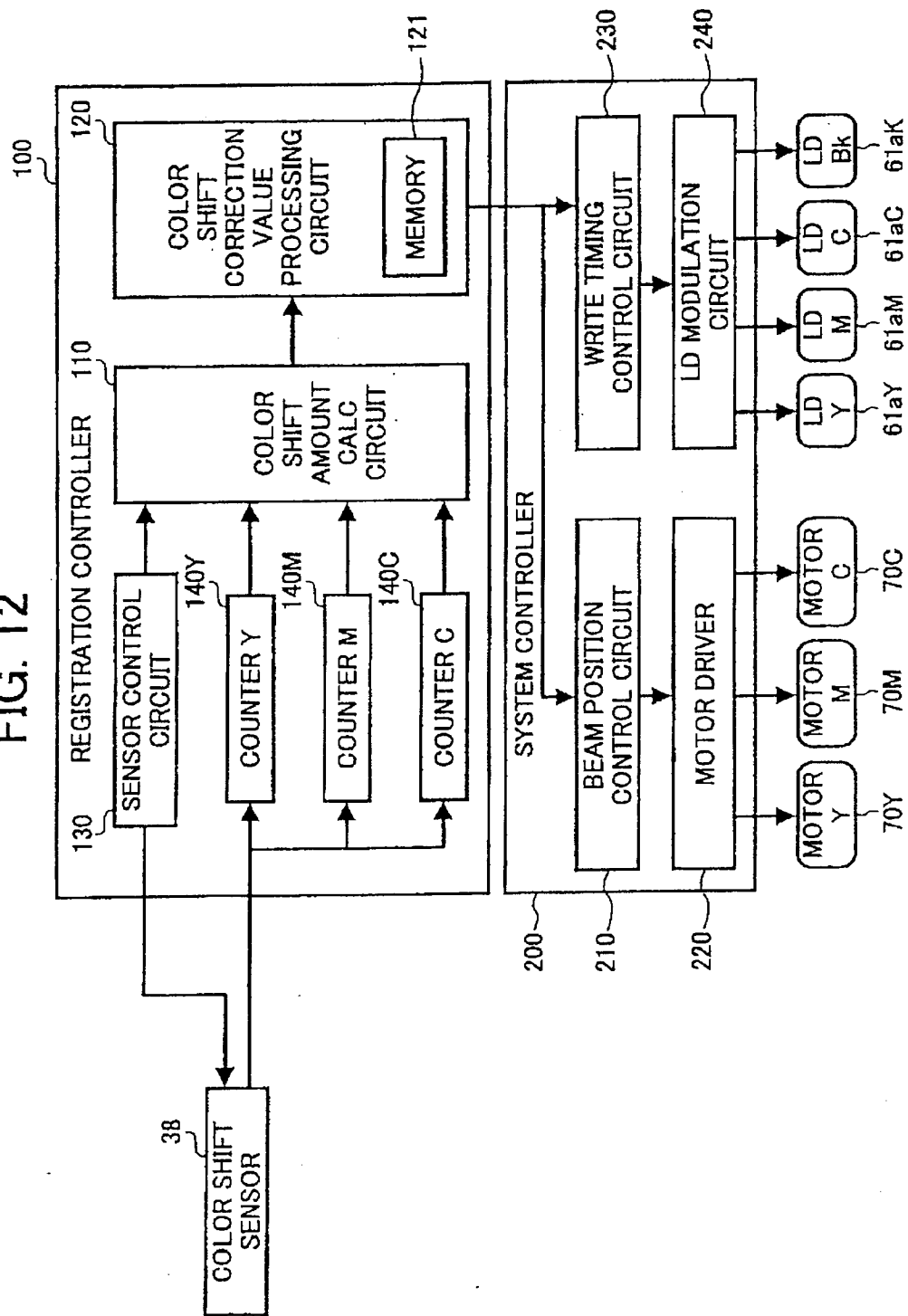


FIG. 13

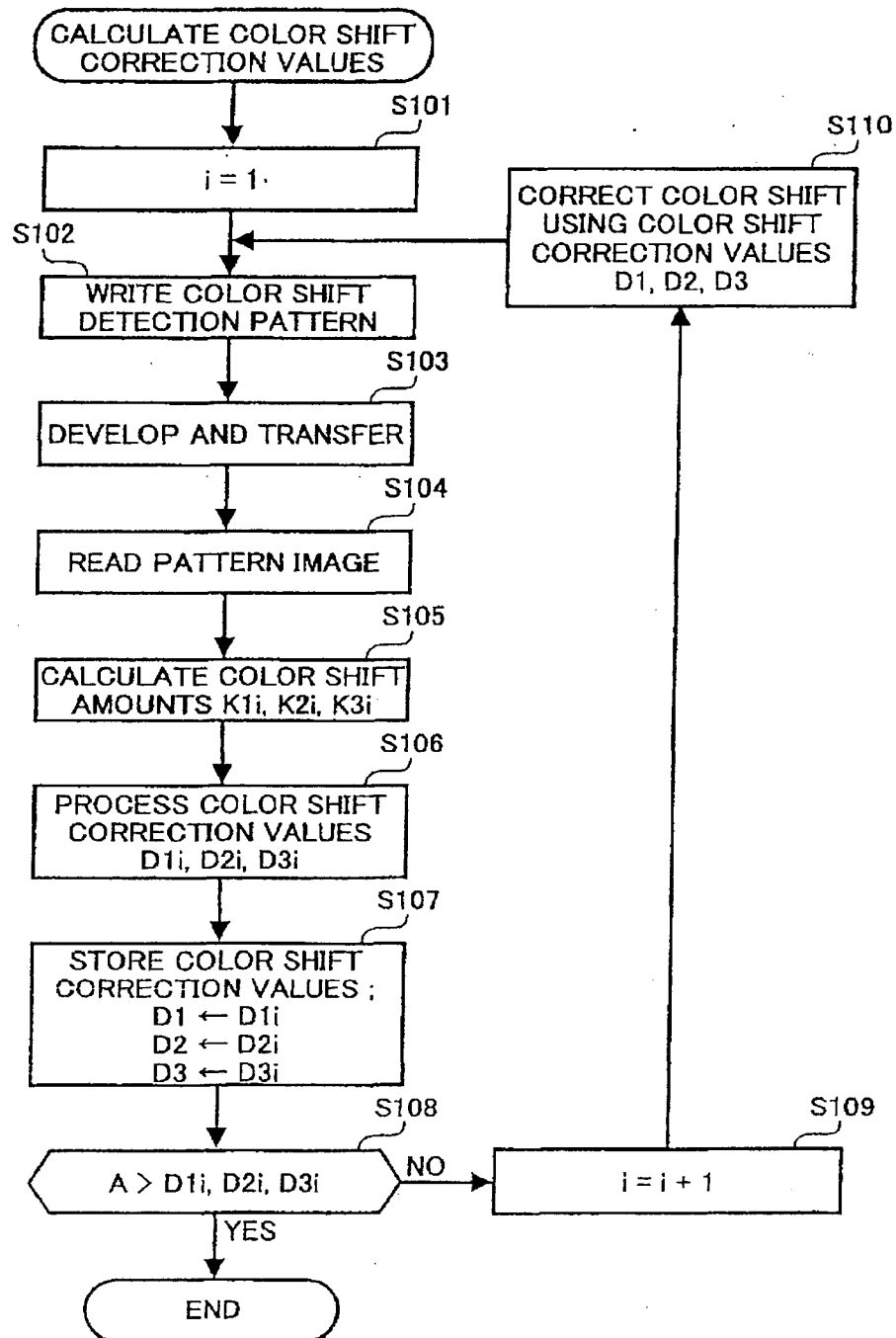


FIG. 14

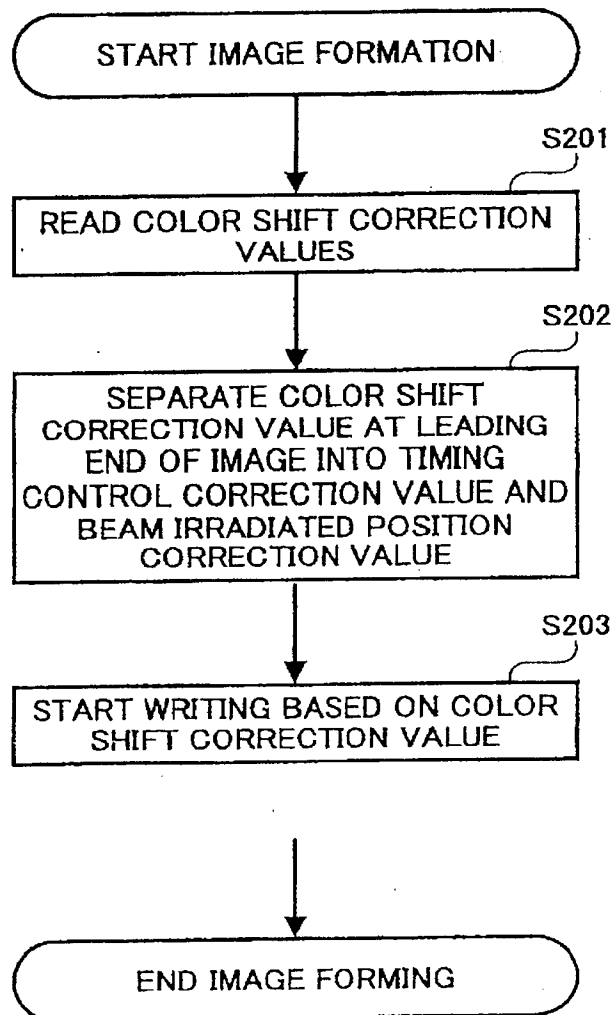


FIG. 15

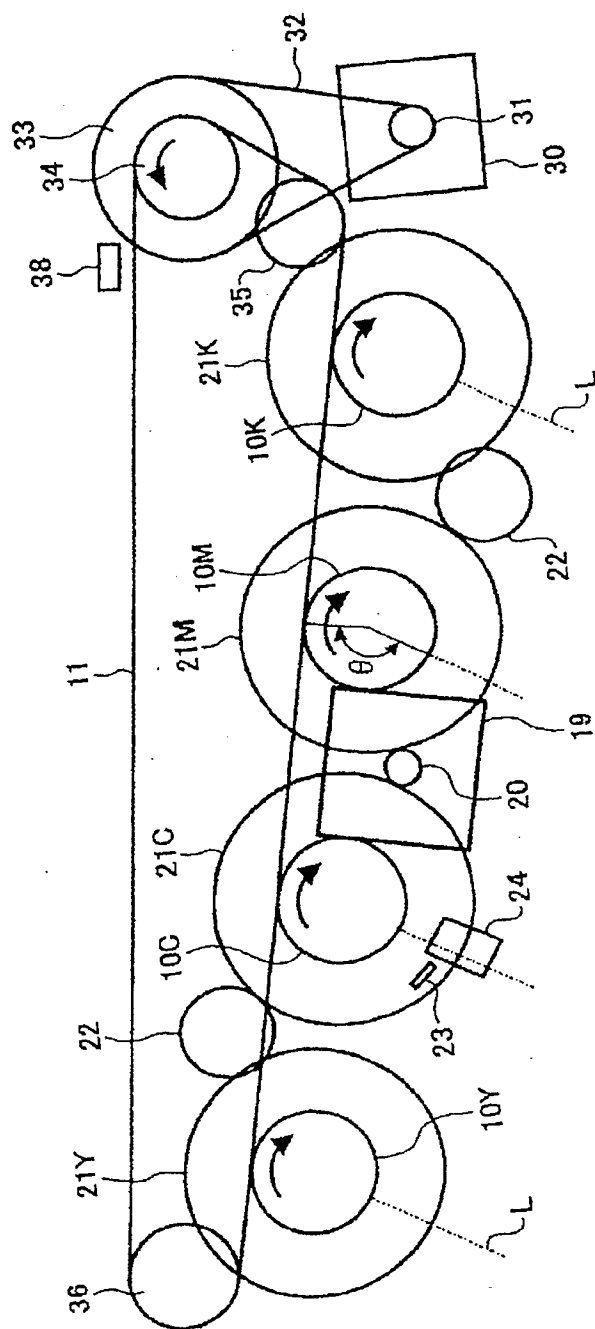


FIG. 16

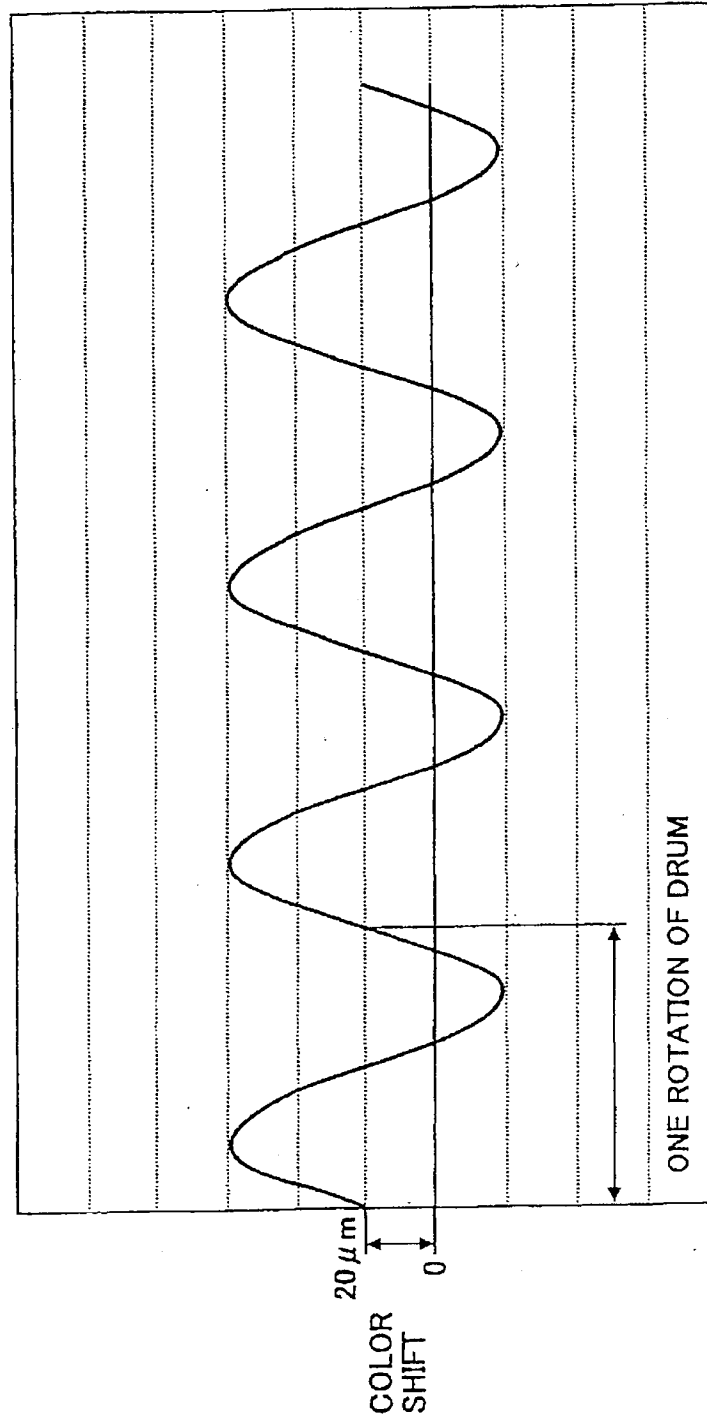


FIG. 17

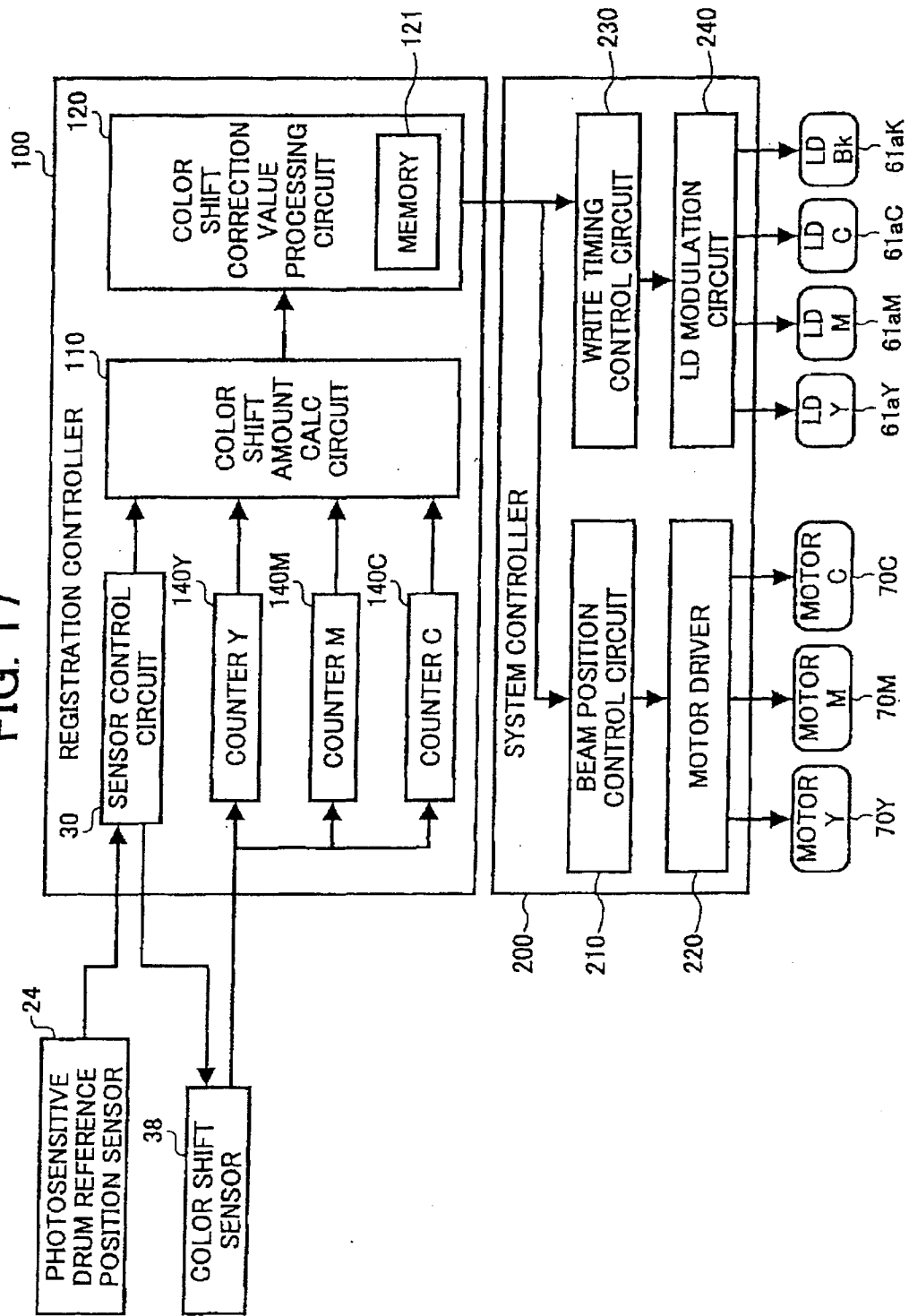


FIG. 18

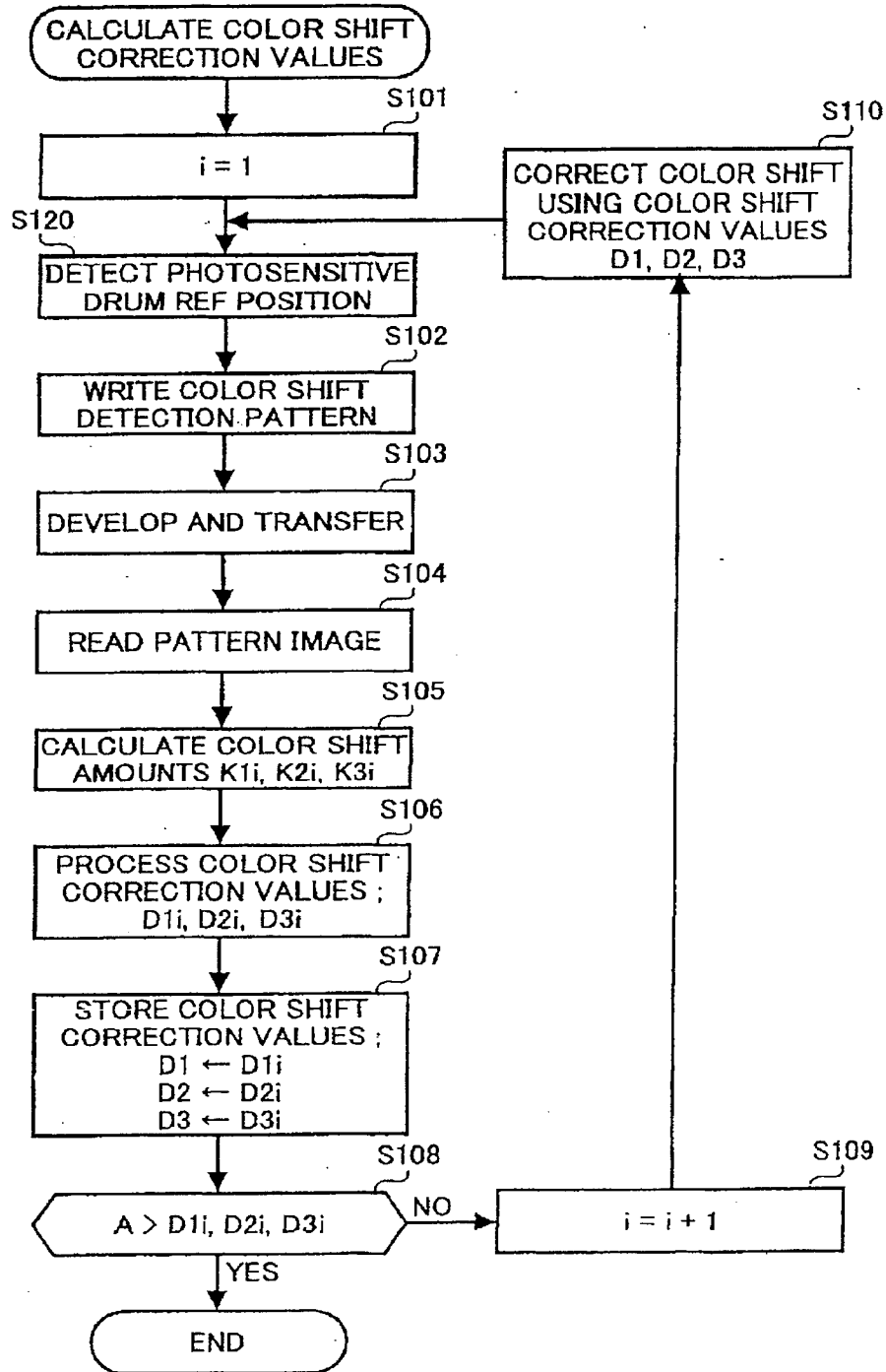


FIG. 19

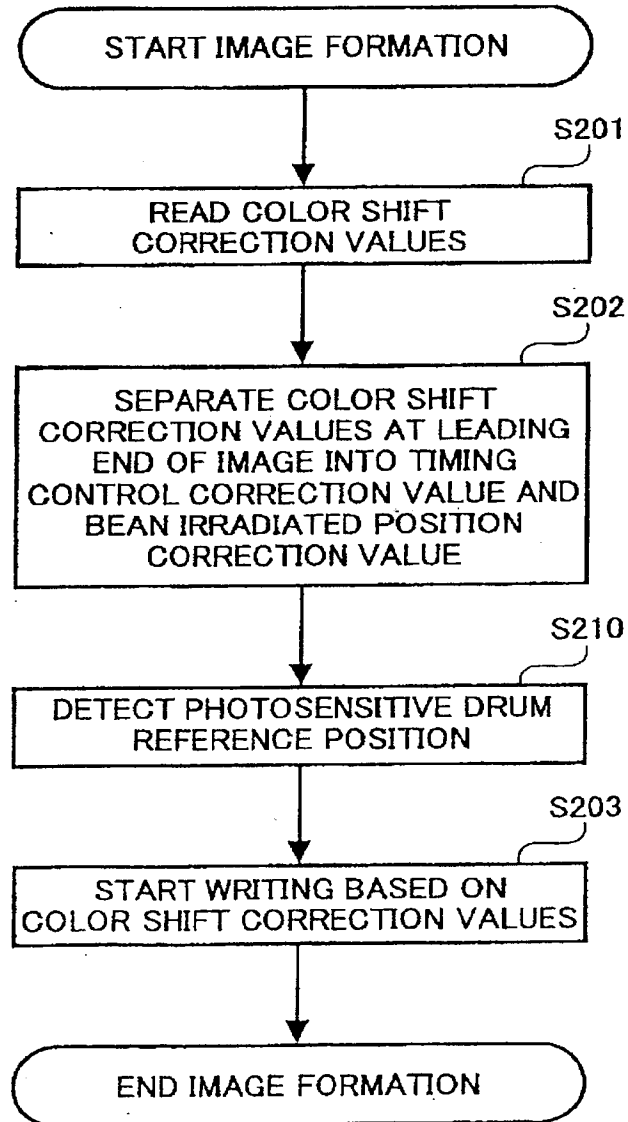


FIG. 20

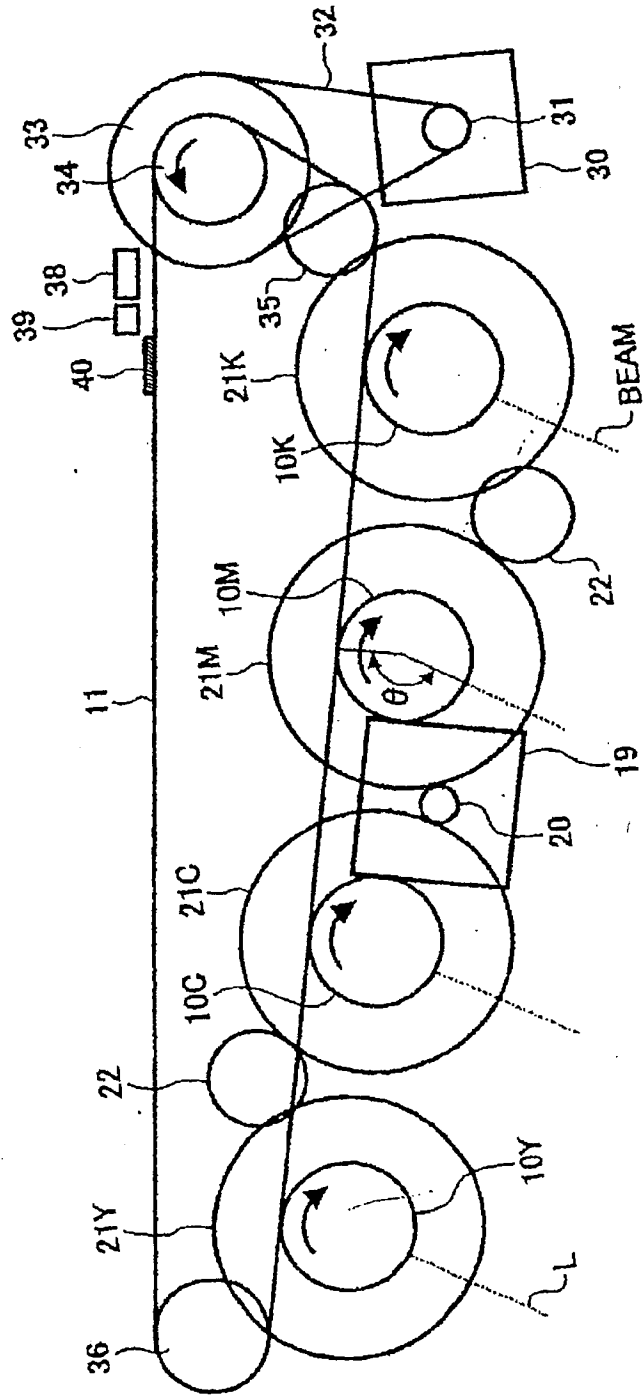


FIG. 21

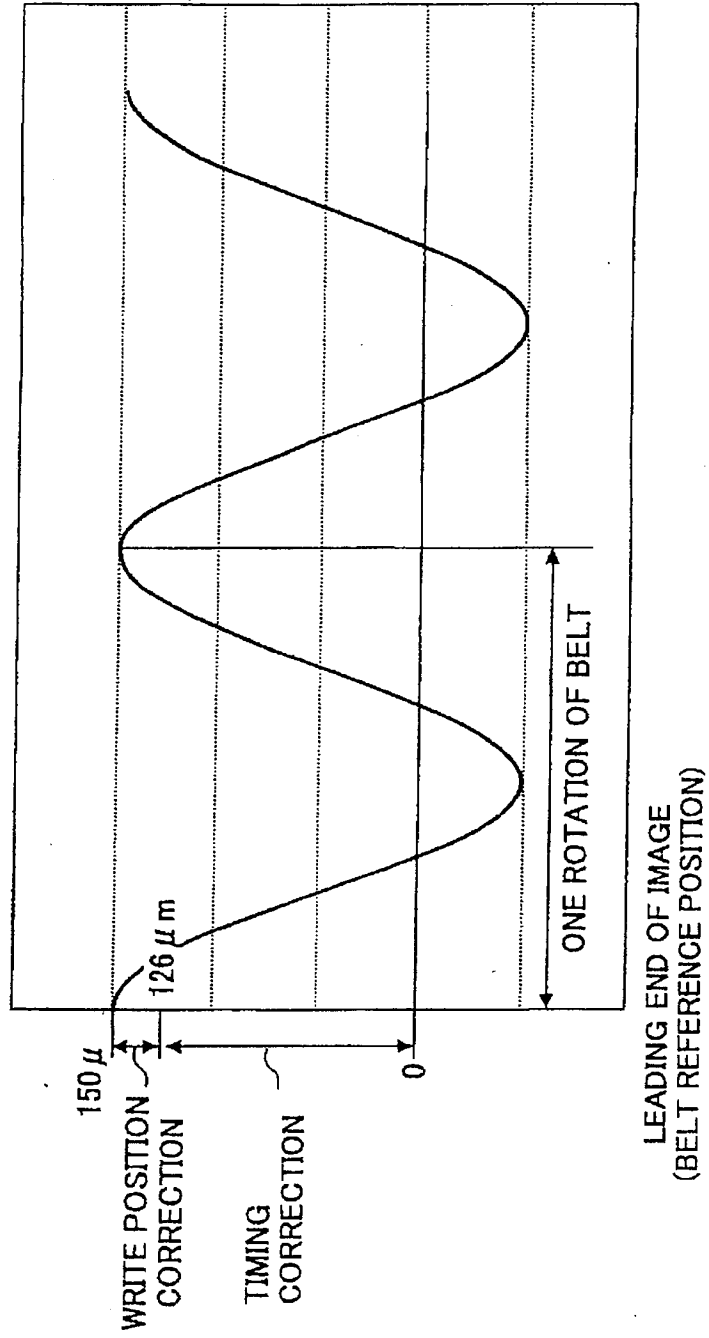


FIG. 22

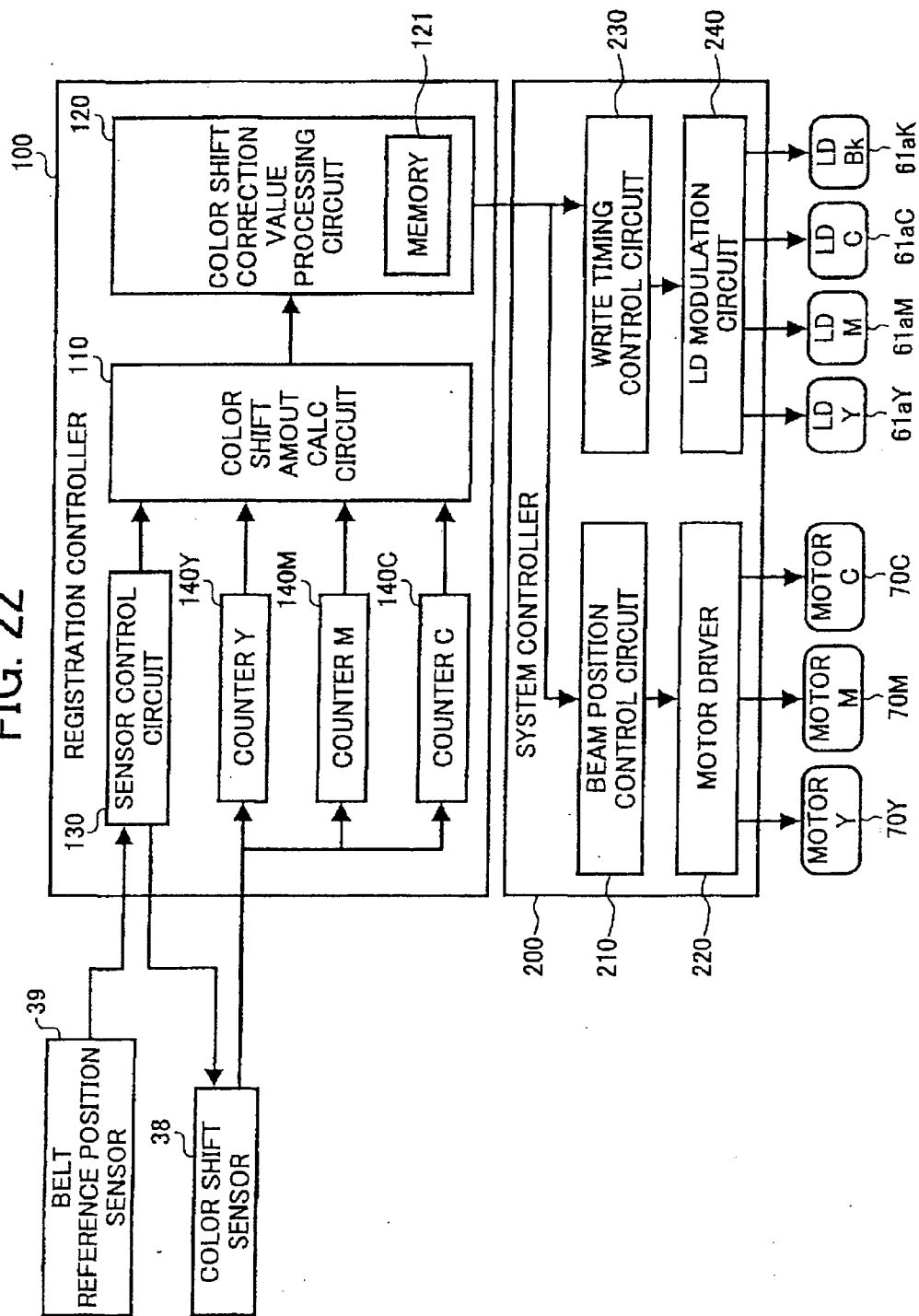


FIG. 23

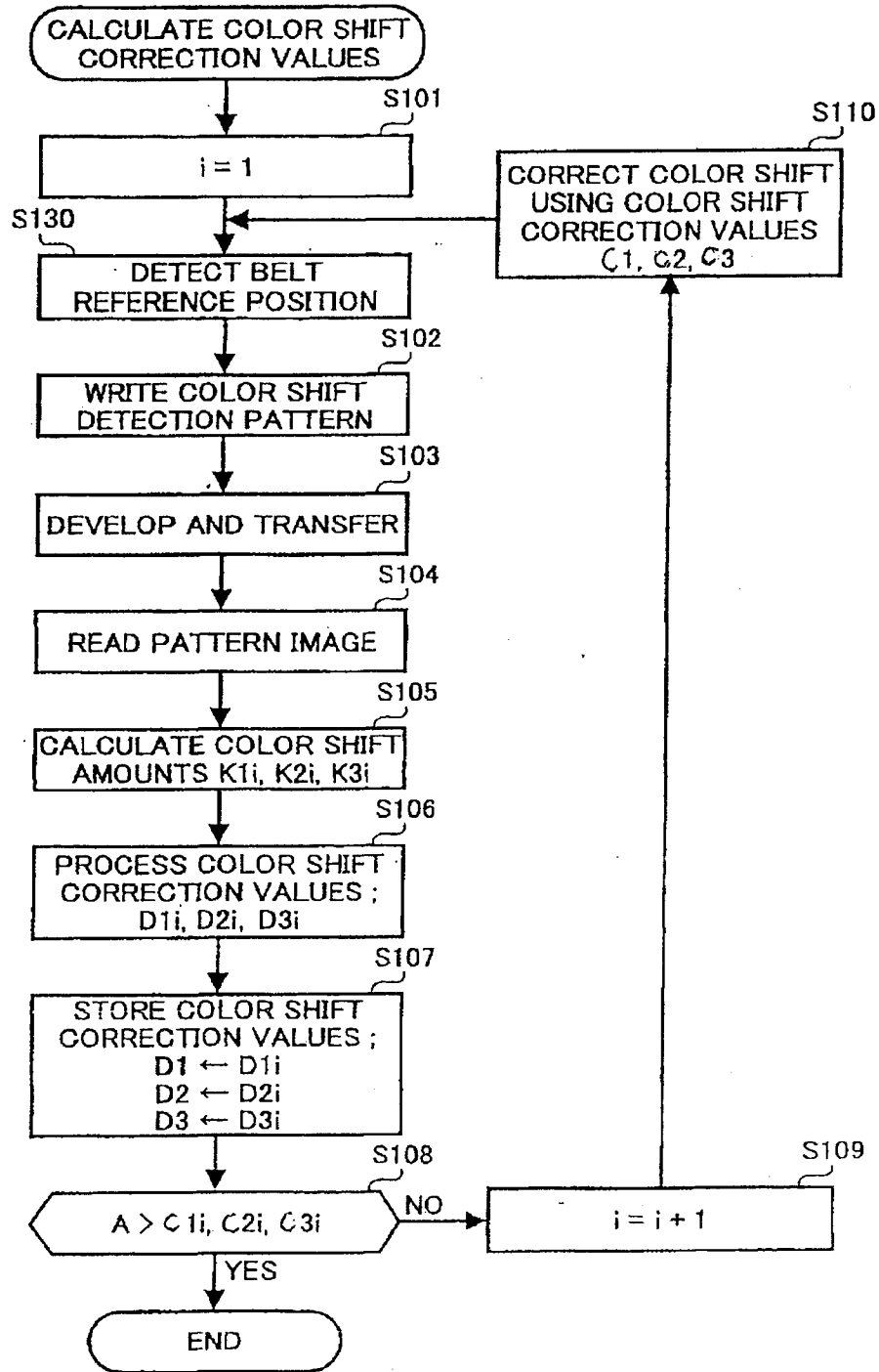


FIG. 24

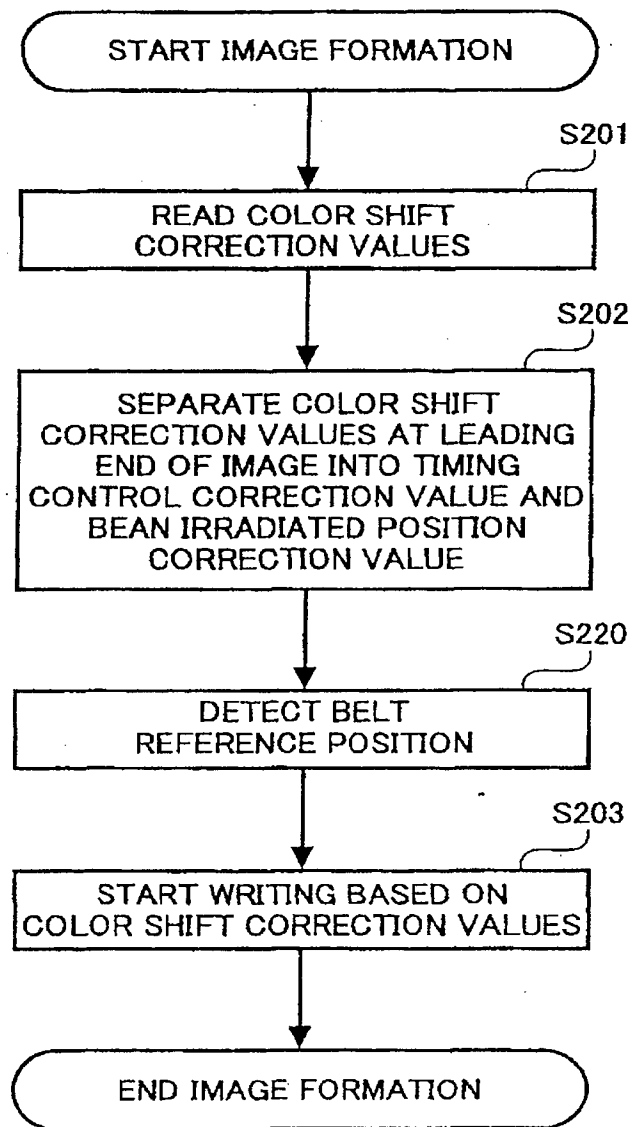


FIG. 25

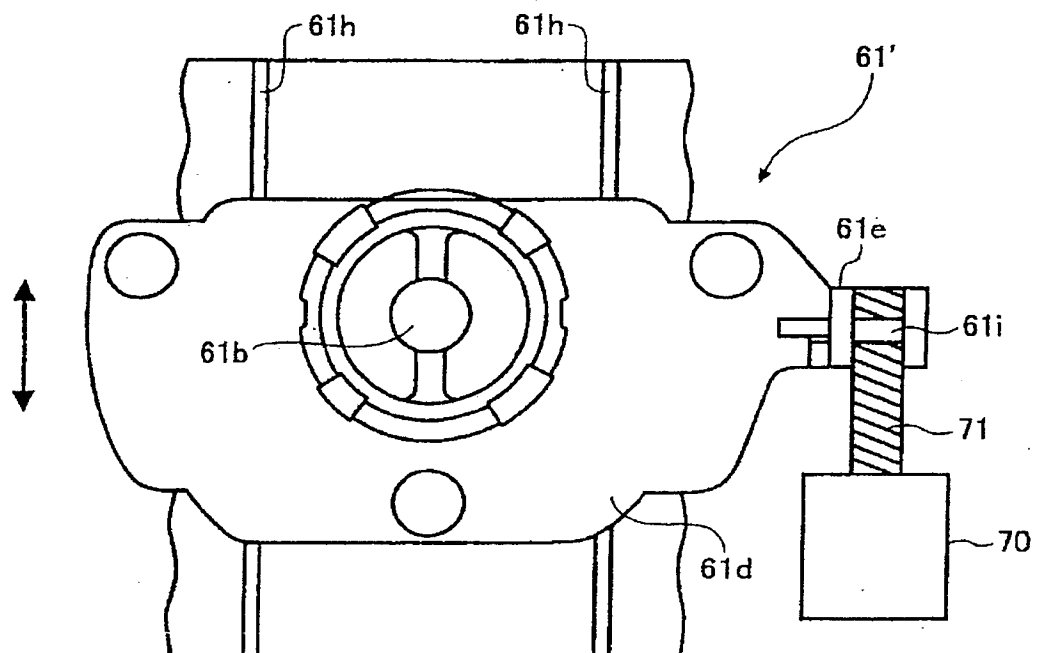


FIG. 26

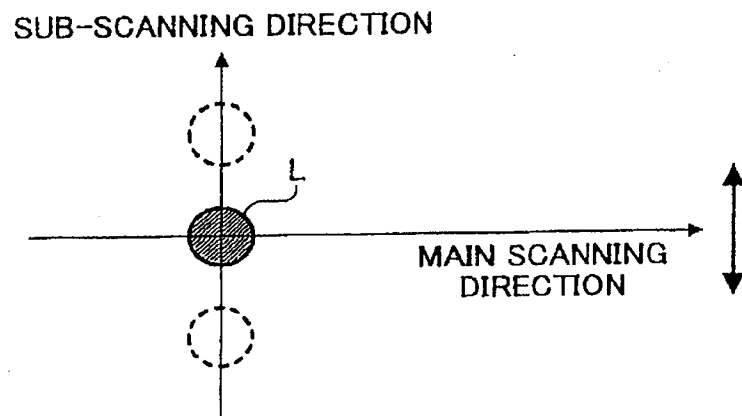


FIG. 27

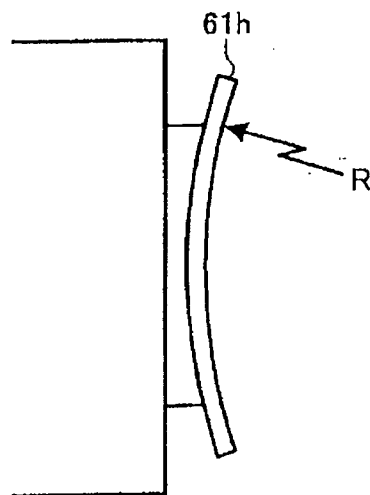


FIG. 28

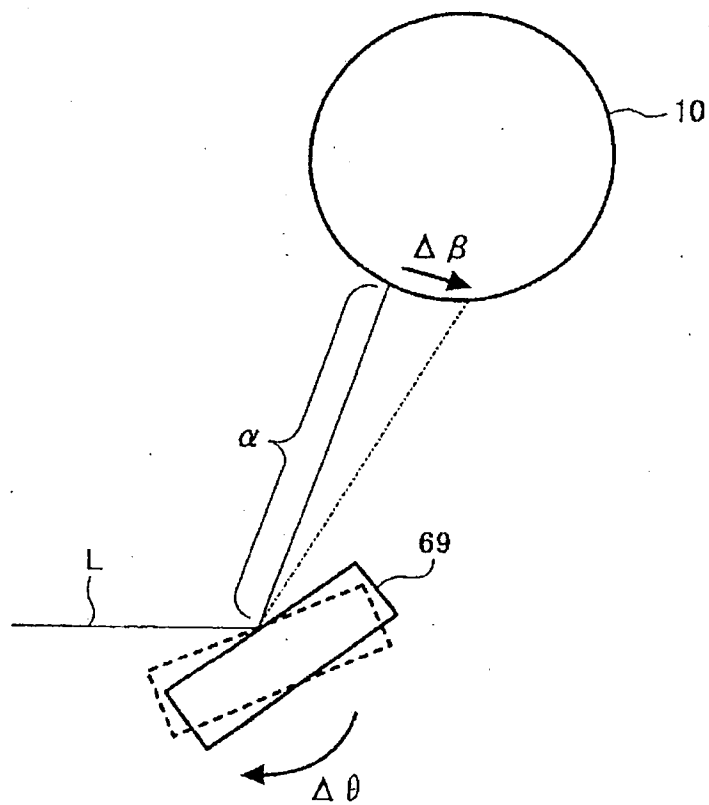


FIG. 29

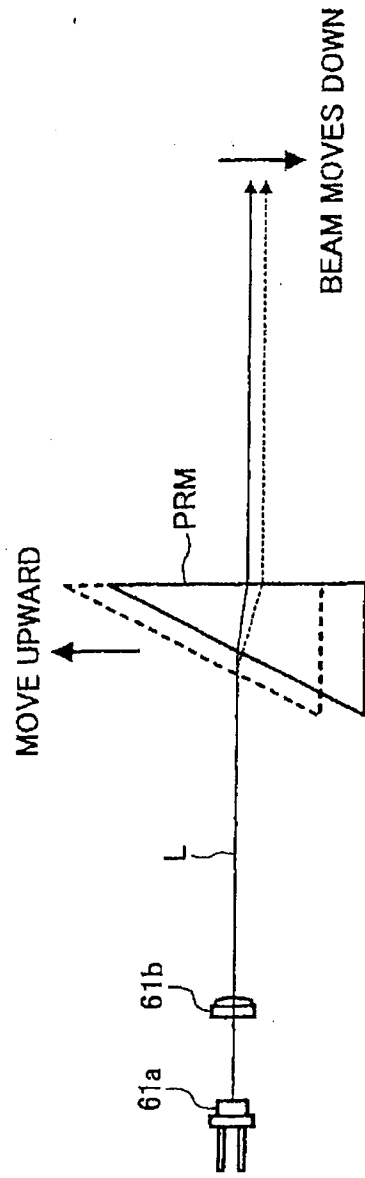


FIG. 30

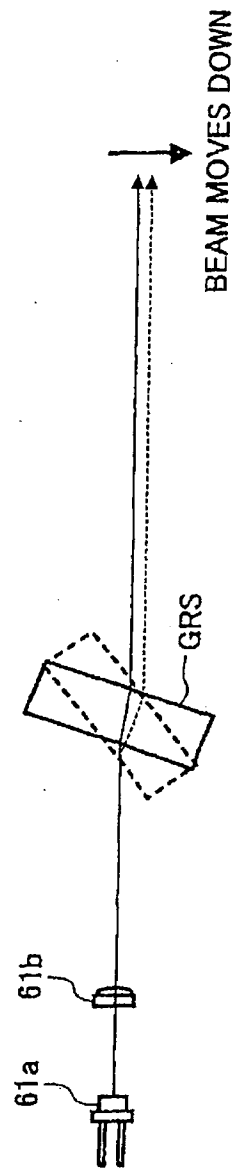


FIG. 31

